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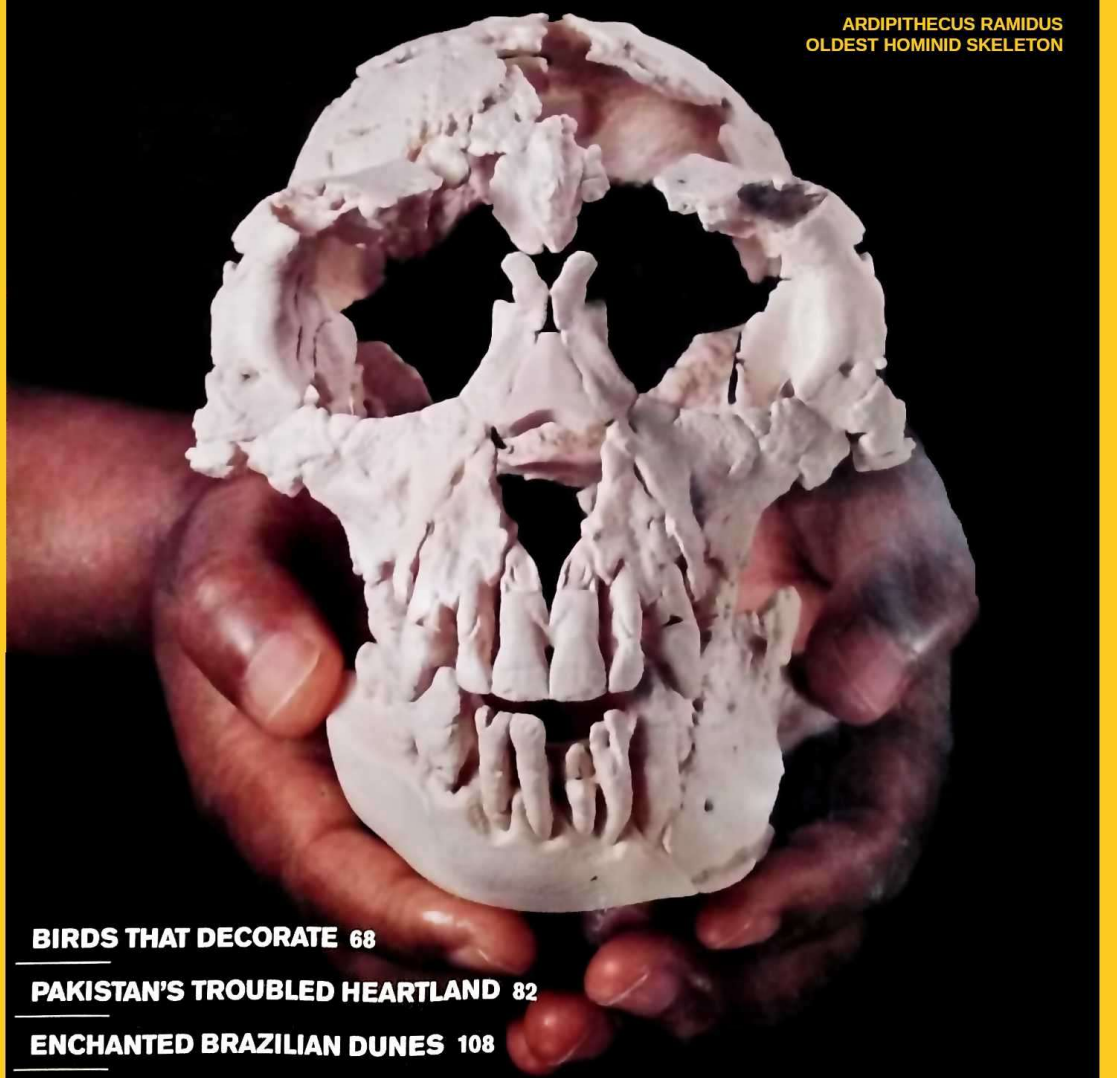
NATIONAL GEOGRAPHIC

4 Million Year Old Woman

ARDIPITHECUS RAMIDUS
OLDEST HOMINID SKELETON



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NATIONAL GEOGRAPHIC

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On the Cover Alemu Ademassu, a technician at the National Museum of Ethiopia, holds a resin recreation of the 4.4 milion year old skull of *Ardipithecus ramidus*. Photo by Tim D. White

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EDITOR'S NOTE

My grandfather must have been thinking ahead.

As a young man in the 1920s, George C. Johns built a house in Vernonia, Oregon. The town was headquarters for the Oregon-American Lumber Company, then one of the largest lumber firms in the Pacific Northwest. There wasn't much of an electrical grid in those days. Smaller towns (like Vernonia) near industrial centers were more likely to have electrical access than those that were more isolated. Rural folks had it even harder. Only 10 percent of American farms were electrified. Private electric companies had little interest in extending power lines to the countryside.

Posters helped publicize the benefits of the Rural Electrification Administration in 1937.

All that changed in 1935 when Franklin Roosevelt established the Rural Electrification Administration. The REA provided low-interest loans to farmers, who formed their own cooperative groups to bring in lines and manage the power. By the end of the 1940s some 90 percent of farms had electricity. The grid was finally in place.

The drudgery of life before electrification is a rapidly vanishing memory, as Joel Achenbach makes clear in this month's story about the grid. Though perhaps you can remember — for a price. The other day I saw a real estate listing for a rural Oregon property near where I grew up. The log A-frame had one bedroom, two baths, and antique furniture that conveyed with purchase. Its big selling point seemed to be a promise of luxury living off the grid. It was priced at more than a million and a half dollars.

I wonder what my grandfather would have thought of that?

POSTERS: "LIGHT", "WASH DAY", "FARM WORK", AND "RUNNING WATER" BY LESTER BEALL, 1937; ART © LESTER BEALL, JR., TRUST/LICENSED BY VAGA, NY; LESTER BEALL COLLECTION, GRAPHIC DESIGN ARCHIVES, CARY GRAPHIC ARTS COLLECTION, RIT ("WASH DAY" AND "FARM WORK")

LETTERS

March 2010

Wolf Wars

Although I was happy to see a wolf on the cover this month, I was disappointed in the article's coverage. To state that "humans are at war with wolves. It is an ancient dispute" is both sensational and ethno-centric. Nowhere in your article did you include perspectives from tribal members in wolf country, who are the only people who have anything to say about a truly ancient relationship with wolves. The Nez Perce tribe would have been a good place to start since its government has partnered with the Department of the Interior to initiate wolf recovery in the region.

DAVID MOEN
Oregon City, Oregon

It is shocking that ranchers hate wolves when wolves take only one percent of reported sheep losses compared with coyotes taking 25 percent, and wolves kill or drive away coyotes. How can hunters hate wolves when wolves cull the sick and weak from elk herds, improving the conditions for the trophy bucks? Author Douglas Chadwick quotes one rancher as acknowledging that "the general U.S. population wants wolves". Yes, we do. The wolves belong to all of us, not just the hunters of Idaho or the ranchers of Wyoming. The Statue of Liberty does not belong to me just because I live in New York. It also belongs to those hunters and ranchers. And it will be here when they want to come see it. But will the wolves be there for the rest of us? The Idaho and Wyoming plans are not management, or even trophy hunting. They are plain and simple extermination.

GREGORY DL MORRIS
New York, New York

I find the yammering of many native city dwellers opposed to wolf control to be hampering a just cause. Just as a Montana rancher having a deciding voice in whether more or fewer subways are needed in New York City would be seen as absurd, most ranchers, hunters, and inhabitants of rural areas see it as absurd when those with little perspective chime in on the issue. Wolves are a part of our ecosystem. But just as with other predators, a balance of safety, economy, and preservation needs to be hammered out by knowledgeable individuals.

MICHAEL HARMON
Spokane, Washington

We can live with wolves. Non-lethal methods, like livestock-protection dogs, high-tech fencing, fladry, cattle rotation, and more, work even better than just shooting them to death. And as far as elk and other species' numbers going down, that's what happens when you have another species move in and that species increases in number. But predators don't wipe out their prey base. They would starve to death if they did.

MIKE WAGNER
Louisville, Colorado

You ask whether we want to include the wolf in conserving wildlife communities, but the answer will never come. As the pendulum swings for survival of every species, human beings sit at the top of the food chain and manage all below. We too are natural hunters, and not all humans in the West are interested in trophies to hang in our living rooms. Many of us hunt and fish to put food on the table. Perhaps your question should be rephrased: in conserving wildlife communities, do we want to include human beings, or not?

BONNIE ANGLIN
Tandoy, Idaho

I enjoyed the "Wolf Wars" article. Facts on wolves are desperately needed here in Idaho. Unfortunately, most of the anti-wolf people won't let their opinion be confused by facts. It seems some really think they are saving Little Red Riding Hood and the Three Little Pigs.

GREG LEWIS
Kamlah, Idaho

Corrections, Clarifications

March 2010: Africa's Last Frontier

Page 104: Ethiopia was incorrectly described as the only African nation never colonized by Europeans. Liberia was never a European colony.

Email ngsforum@ngm.com

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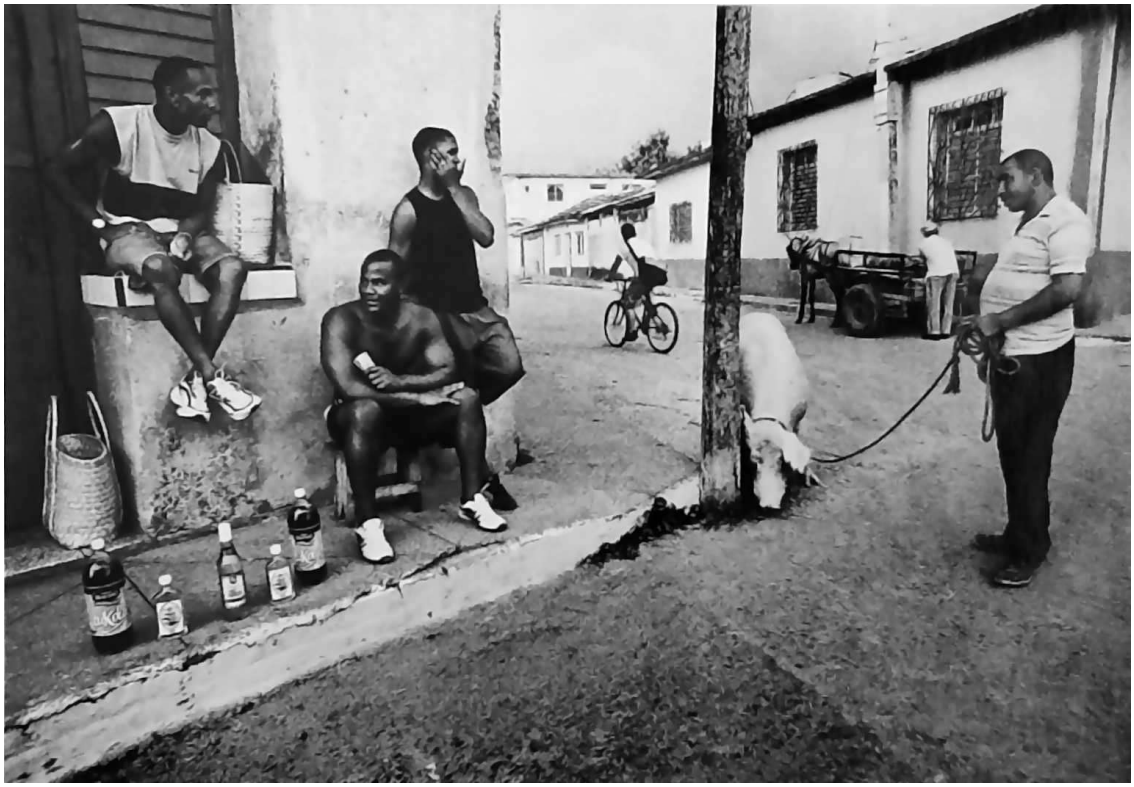
Compare and Contrast Color is great, but don't forget about black and white. Nearly any kind of image — whether it's an unusual street scene or wave-lashed rocks in a violent storm — can gain subtlety and depth in monochrome. So give B&W a shot, then send your best to us. Every month this page features two photographs: one chosen by our editors, one chosen by our readers via online voting. For more information, go to ngm.com/yourshot.



EDITORS' CHOICE

Luis Zilhão Neuberg, Germany

Visiting Cuba, the 41-year-old Zilhão hoped to "meet ordinary Cubans and get into their way of life". He got his wish while chatting with locals in the town of Trinidad — except the ordinary became extraordinary when "a man came along with a huge pig on a rope!"

Tom Henry Minneapolis, Minnesota

"Maybe twice a year Lake Superior gets this wild", says Henry, 54, who documented big waves on Minnesota's North Shore. "I had to run away from a few in the time it took to capture this image."

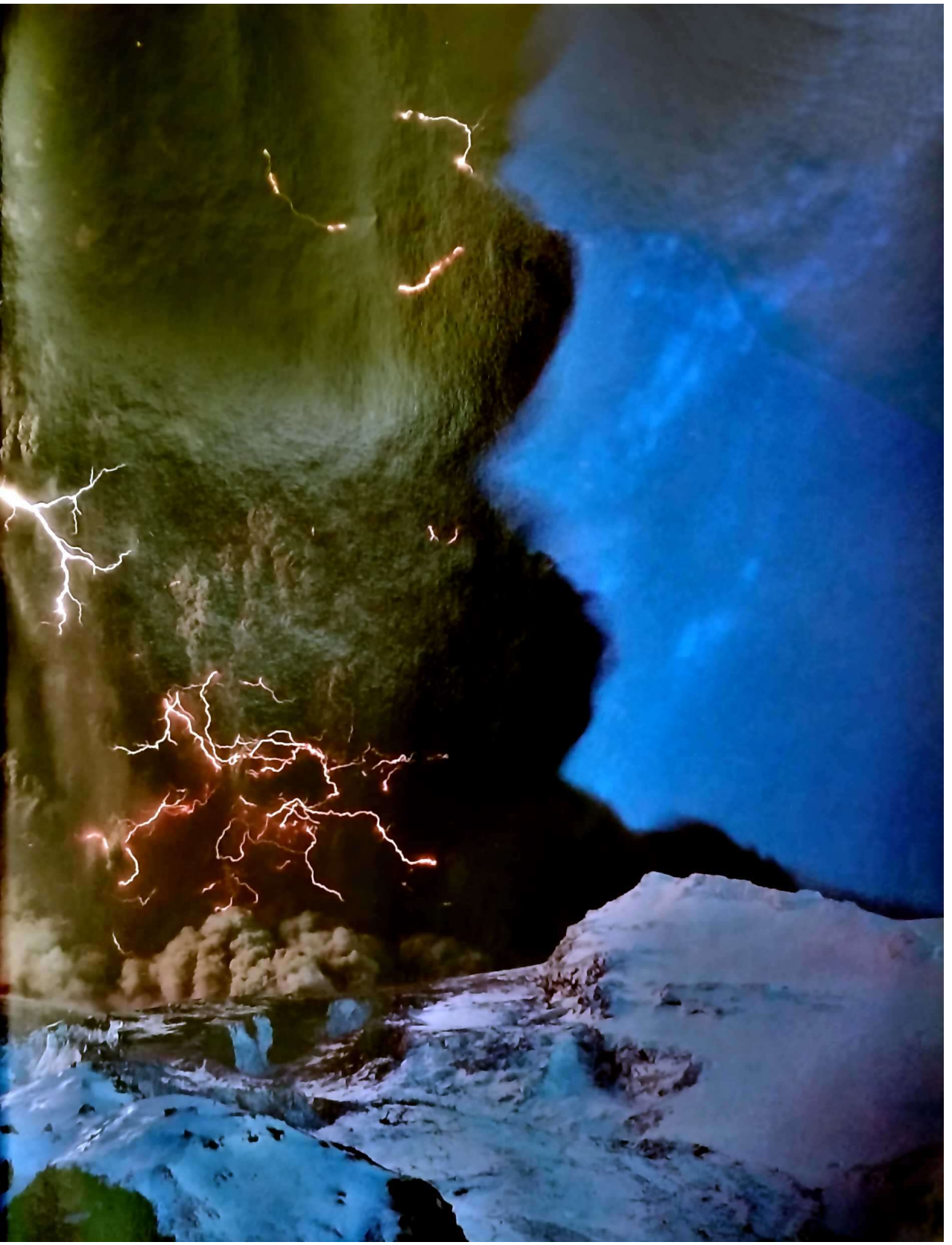
READERS' CHOICE

PHOTO LAURENT MERCEY

Namibia Its bright pouch agape and two-tone wings spanning perhaps ten feet, a great white pelican in Walvis Bay sets its sights on a fish breakfast. These migratory birds are found in Afrlca, Asia, and Europe.

Iceland Lightning veins the Eyjafjallajökull volcano's ash plume, which roiled air travel this spring. Such "dirty thunderstorms" may occur when rock and ice particles loosed by exploding magma collide in the atmosphere.

PHOTO: SIGURDUR HRAFN STEFNISSON



United States Big city, short game: Resident Charlie Bernhaut works on his stroke 34 stories above 63rd and Broadway, on his condominium's 18-by-32-foot putting green — one of several now lining rooftops in Manhattan.

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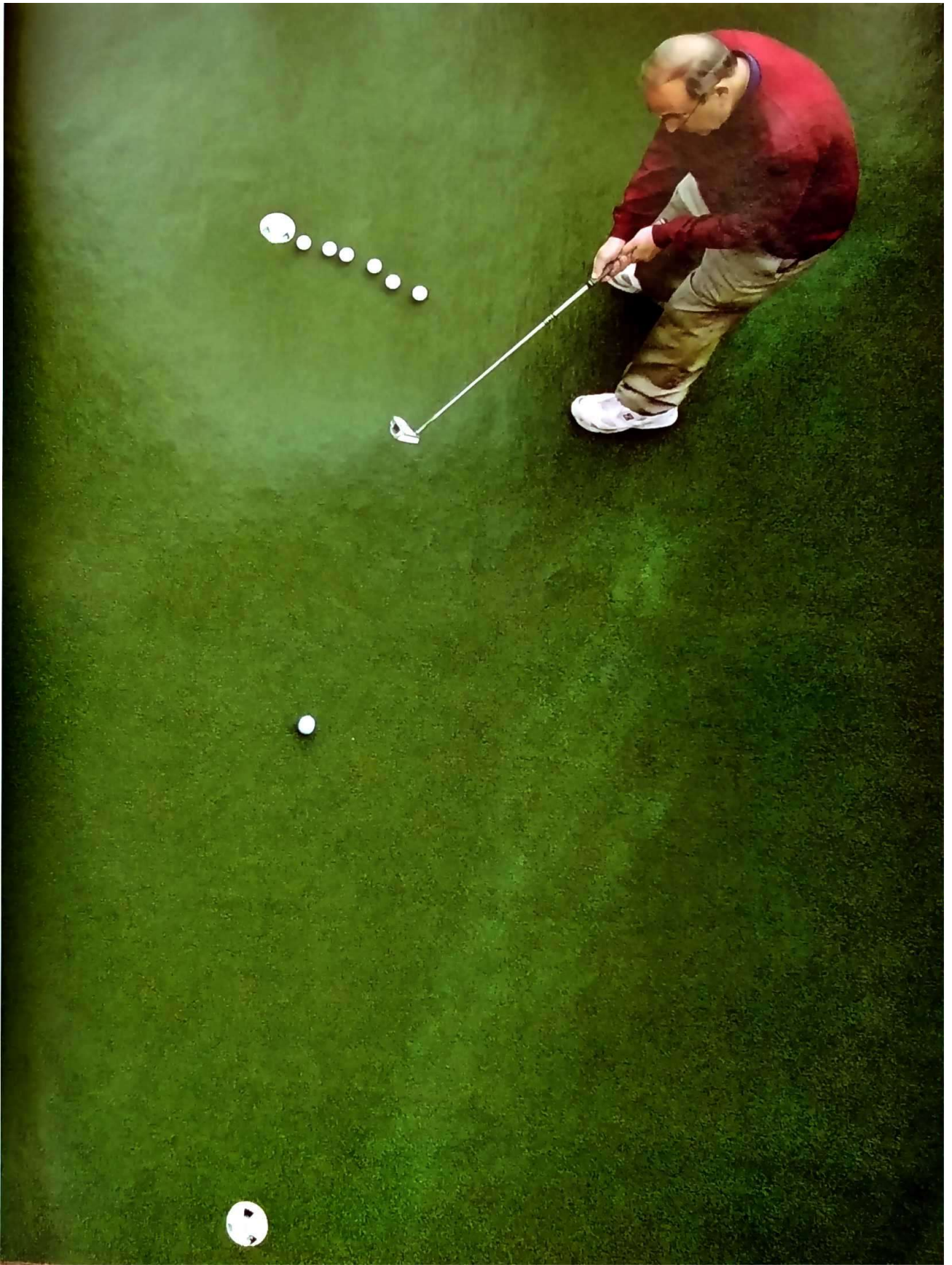
PHOTO: LANDON NORDEMAN



Mooning Over Solar Eclipses

Want to know when and where you can witness the shading of the sun?
We map the next three events sure to lure "umbraphiles" from around the world

As day plunges into night, the faithful gaze skyward, murmuring in awe. They wear Mylar glasses, hoist cameras, join hands. They are "eclipse chasers," and their numbers have been growing since the 1970s.

Total solar eclipses occur every 18 months or so and are visible for just a few minutes from any one spot. As knowledge about them has trumped superstition, legions of fans have been flocking to the narrow strips on Earth where the moon can best be seen obscuring the sun (map). The reward for these so-called umbraphiles, says Williams College astronomy professor Jay Pasachoff, is "the most dramatic natural phenomenon ever visible. It's spectacular and fills you with awe. A primal feeling comes over you."

This year Melita Thorpe, owner of an astronomy-themed travel agency, saw a hundred slots fill up by spring for a $6,000 July freighter trip to the South Pacific; dozens more devotees signed up for a sunset viewing of the same eclipse in Patagonia. Her biggest crowd in the agency's 26 years: the 700 people she ferried to view a 1991 eclipse off the coast of Mazatlán, Mexico.

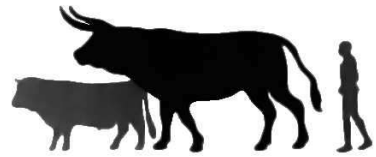
For most enthusiasts, one experience is not enough. But don't ask them to pick a favorite. Says Bill Kramer, editor of the popular website *eclipse-chasers.com*, "The most important one is the one I'm about to see." —*Jeremy Berlin*

MAP: SAM PEPPLE, NGM STAFF. SOURCES: NASA, XAVIER M. JUBIER
PHOTO (COMPOSED OF 55 CALIBRATED IMAGES): MILOSLAV DRÜCKMULLER, PETER ANIOL, VOJTECH RUŠIN

Ox Redux For centuries they roamed Europe's forests — massive bovines called aurochs that were depicted on cave walls by Paleolithic artists (inset) and prized as hunting trophies. They died out nearly 400 years ago. Now genetics may bring them back to life.

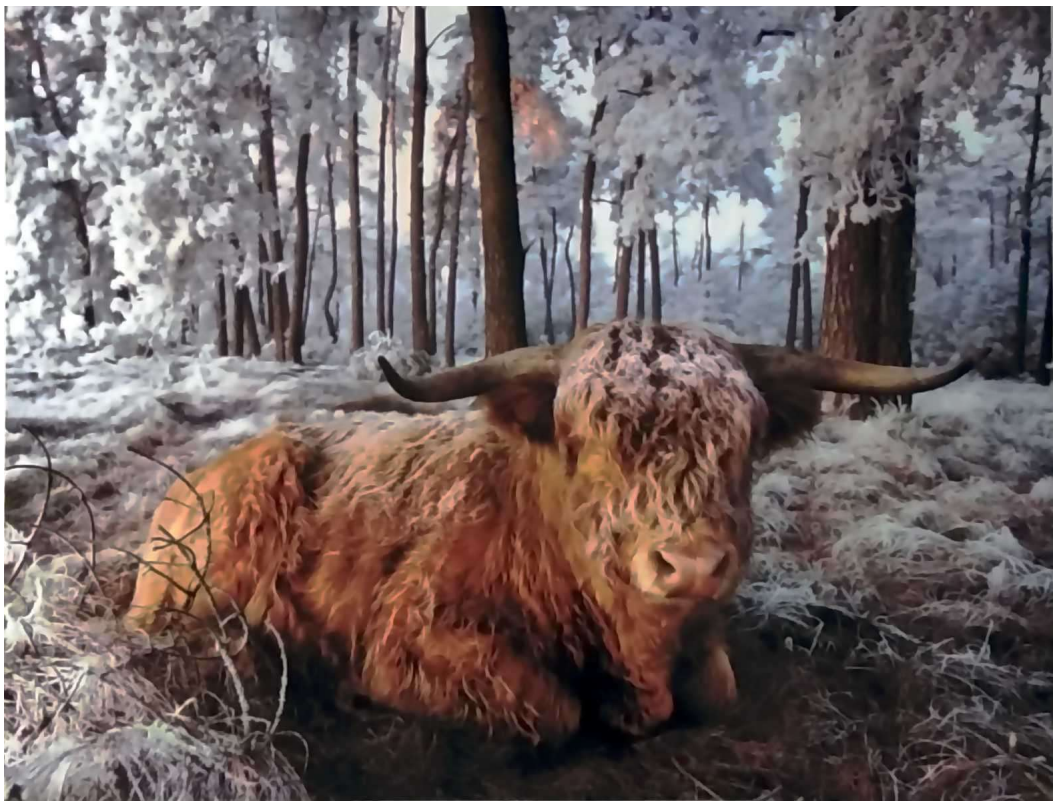
Sound like a Jurassic Park sequel? It's actually the real-life plan of Project Tauros, a consortium of European scientists using DNA sequenced from aurochs teeth to steer a novel breeding program. Project researchers are currently identifying living cattie — including Spanish Limiana and Italian Maremmana — that still carry aurochs genes. Then breeders wlll cross those cattle to retain the pertinent DNA, jettison the rest, and make bovines that, in about a decade, are expected to look and act just like their extinct ancestors.

Aurochs were herbivorous behemoths, and in the past they browsed on beech, a type of tree now choking Europe's woods. Today such housecleaning would help regrow native flora — as one resurrected species gives other, threatened ones a shot at survival. — *Juli Berwald*

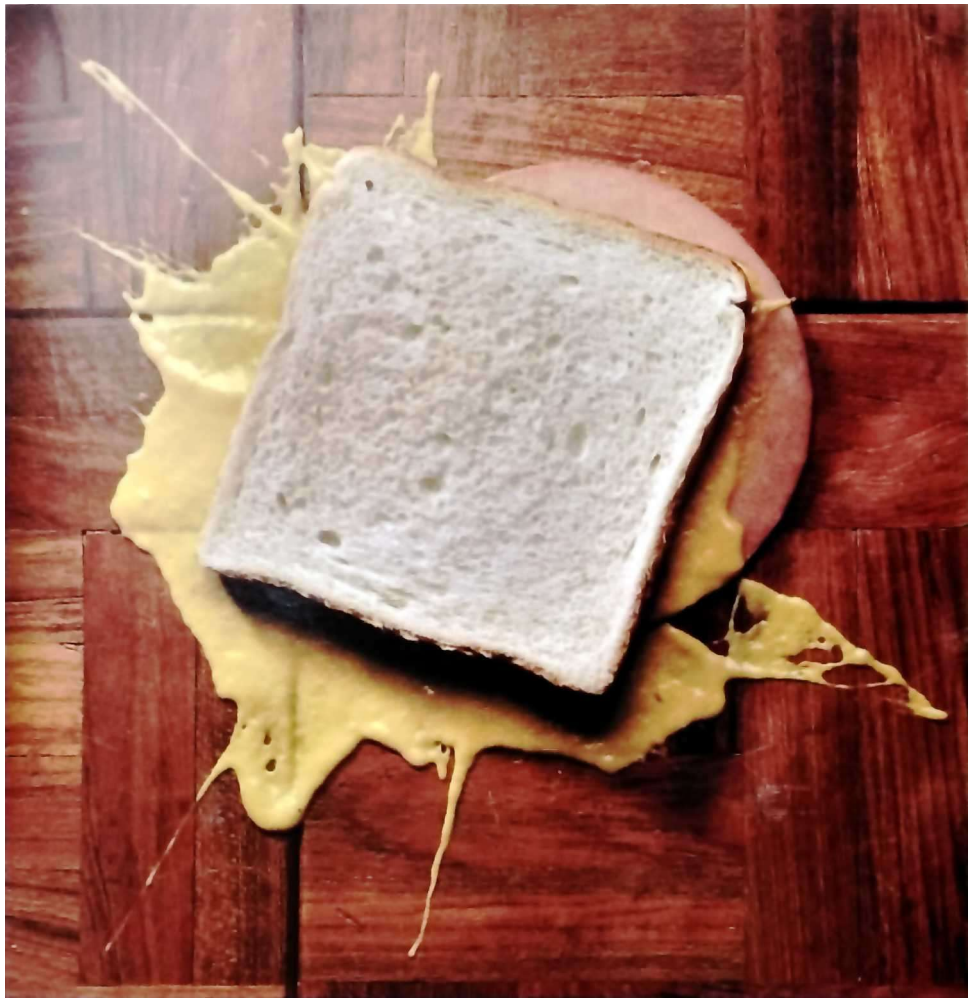


Aurocha stood some six feet high at the shoulder, two feet taller than many modern bovines.

PHOTOS: ADRI HOOGENDIJK. FOTO NATURA/MINDEN PICTURES (BELOW); VISPIX, NGM ART



Scottish Highland cattle, such as this bull in the Netherlands, will be used in early efforts to bring back aurochs.



PHOTOS: REBECCA HALE, NGM STAFF

The Zero-Second Rule Everyone knows the drill: Your tasty treat falls to the floor. You quickly pick it up, pretend nothing happened, and continue eating. Commonly known as the five-second rule, the notion that it takes time to contaminate food is a bunch of baloney, says food-science professor Paul Dawson. His research discovered that salmonella and other bacteria can survive up to four weeks on dry surfaces and transfer to food immediately upon contact. Dawson concluded from more recent experiments that repeated dunking into a dip or sauce using the same edible vehicle, aka double-dipping, is another routine practice that can spread bugs. Although illness may not result, “it's like you're kissing someone”, he explains, “and it's not just a peck on the cheek”. — *Catherine Barker*

Cup sharing
A new study on shared drinks shows the rim and liquid of a single cup can have more than 10,000 bacteria.

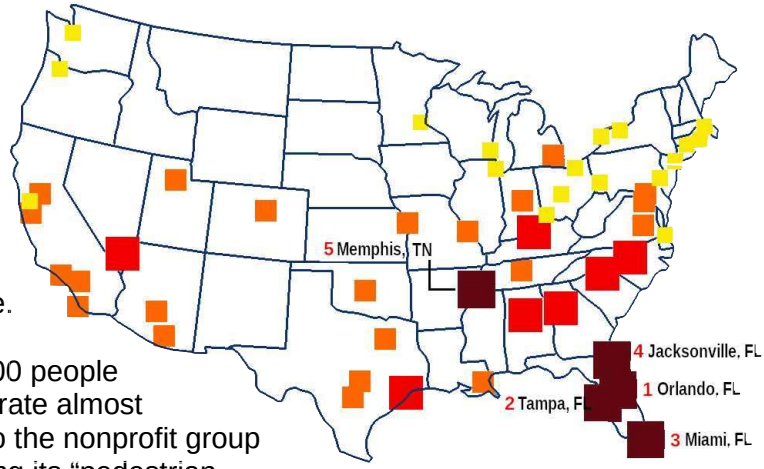
Dip tip
Viscosity matters. Runny salsa totes more germs back and forth than thick guacamole, which drips less.

Chopstick check
Dawson’s team also found that chopsticks and other utensils are effective carriers of bacteria.

Don't Walk in Memphis

The worst city for walkers in the U.S.? Not New York, which ranks among the safest in a 2009 study of pedestrian-unfriendly cities. The four deadliest metropolitan areas are all in Florida: Orlando, Tampa, Miami, and Jacksonville. True, New York has a higher number of fatalities, but with 2.86 deaths per 100,000 people a year, Orlando has a pedestrian fatality rate almost double that of the Big Apple, according to the nonprofit group Transportation for America. When devising its “pedestrian danger index”, which measures risk, the organization took into account the amount of walking people do in each location. Other problem cities include Memphis, Houston, and Atlanta.

Florida’s abundance of older drivers is not to blame for its dubious status. Transportation for America faults the state’s urban sprawl and roads designed to move high volumes of cars as quickly as possible. Still, there's hope for walkers: In Florida and other states the addition of sidewalks, crossing signals, and speed humps has helped lower the number of pedestrian deaths. — *Vikki Valentine*



Pedestrian danger index* (2007-2008) for metropolitan areas of one million people or more

Less risk — More risk

* indicates risk of fatality

Cities with the highest risk of fatality to pedestrians often lack sufficient sidewalks and crosswalks.

PHOTO: KEVIN MEREDITH; NGM MAPS

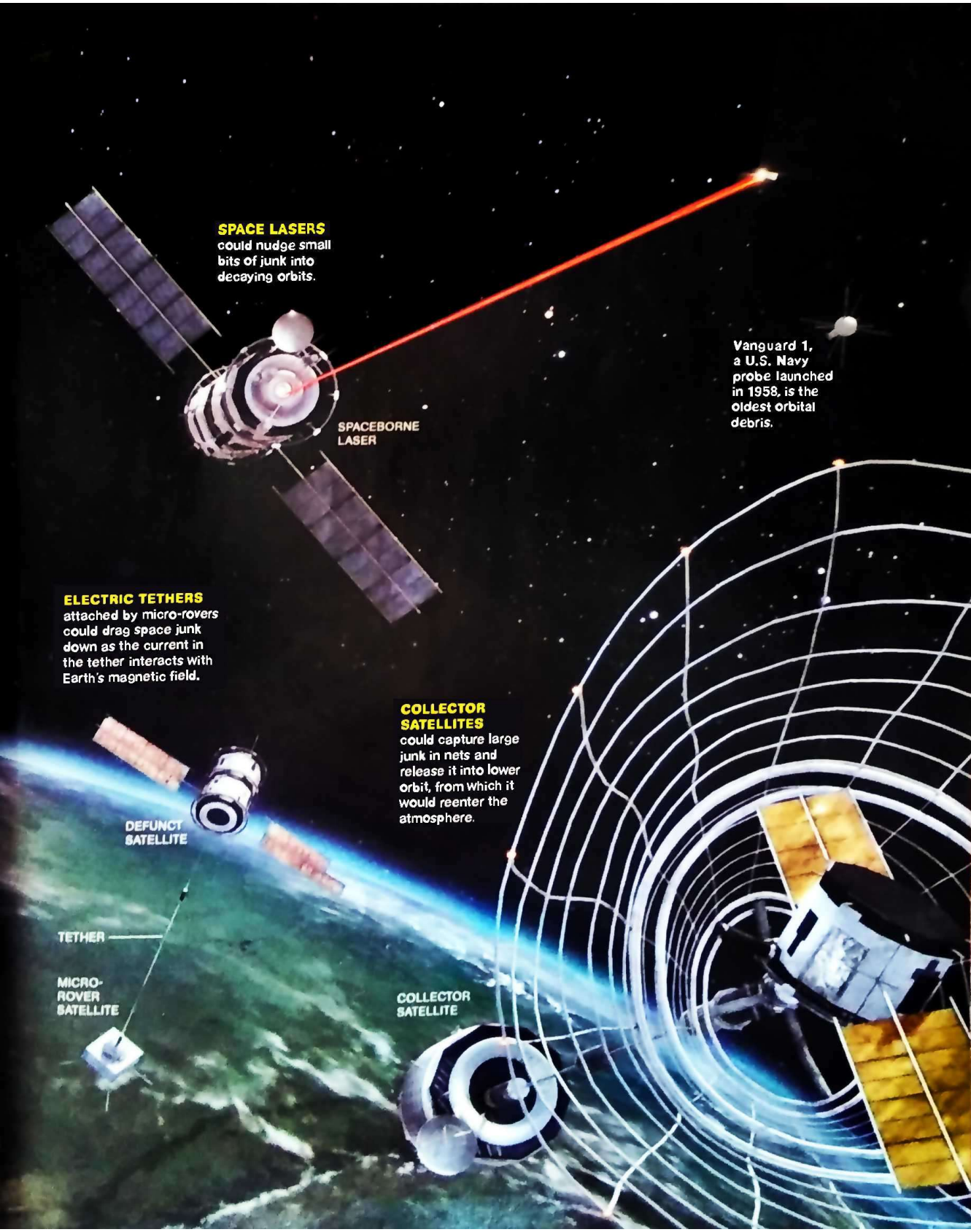
Clearing Space

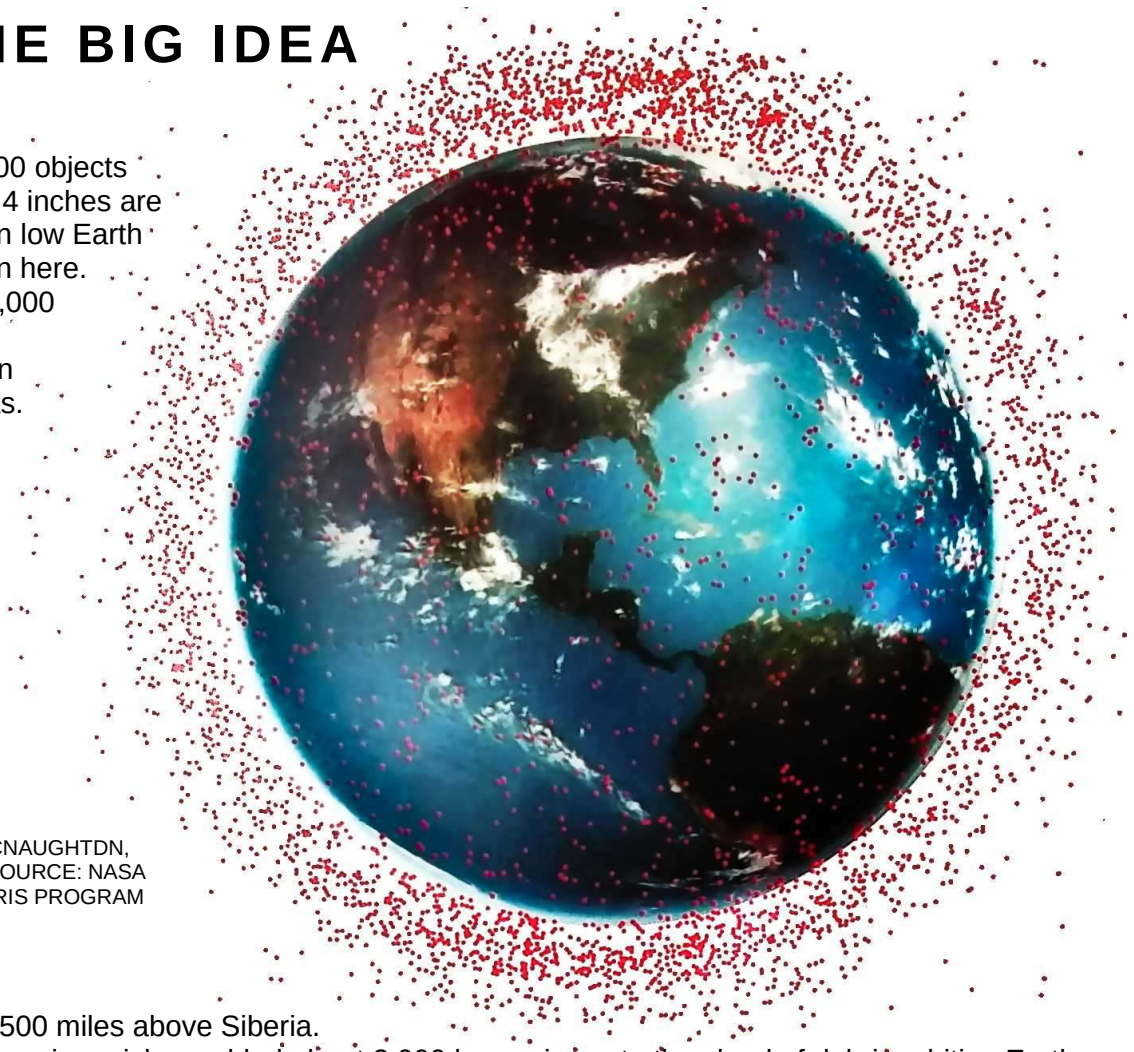
The final frontier is littered with dead spacecraft and shrapnel. It's a hypervelocity menace. How can we clean it up?

OTHER NASA SCIENTISTS worry about getting astronauts off the ground or sending interplanetary probes to Pluto. Nicholas Johnson worries about a nightmare scenario called the Kessler syndrome, named for his colleague Donald Kessler, who first described it in the 1970s. The scenario begins in an overcrowded orbit. Two massive pieces of hardware — satellites, say, or spent booster rockets — slam together at more than 20,000 miles an hour, smashing each other into hundreds of pieces. One piece then collides with another spacecraft, creating hundreds more pieces — and so on, in a slowly building chain reaction that culminates in a belt of space shrapnel too dense for anything to traverse safely.

Until last year, says Johnson, chief scientist at NASA's Orbital Debris Program Office, "the danger was purely academic." But on February 10, 2009, the world witnessed its first full-blown hypervelocity crack-up. An Iridium communications satellite collided with a defunct Russian →

THREE IDEAS for clearing space of junk — including the debris of two satellites that collided in 2009 — would speed the rate at which the debris falls into the atmosphere and burns.


SPACE LASERS
could nudge small bits of junk into decaying orbits.
SPACEBORNE LASER
Vanguard 1, a U.S. Navy probe launched in 1958, is the oldest orbital debris.
ELECTRIC TETHERS
attached by micro-rovers could drag space junk down as the current in the tether interacts with Earth's magnetic field.
COLLECTOR SATELLITES
could capture large junk in nets and release it into lower orbit, from which it would reenter the atmosphere.
DEFUNCT SATELLITE
TETHER
MICRO-ROVER SATELLITE
COLLECTOR SATELLITE



Some 11,500 objects larger than 4 inches are cataloged in low Earth orbit, shown here. Another 10,000 objects are smaller or in higher orbits.

ART: SEAN MCNAUGHTDN, NGM STAFF. SOURCE: NASA ORBITAL DEBRIS PROGRAM OFFICE

→ satellite 500 miles above Siberia. That one alarming mishap added about 2,000 large pieces to the cloud of debris orbiting Earth.

Last December NASA and the Department of Defense hosted an international conference on ways to clean up the mess. The world's space agencies already track the larger bits of trash, allowing spacecraft, especially manned ones, to evade them. And in 2007 the UN recommended some sensible preventive measures, such as draining propellant from spent boosters to keep them from exploding, and not using old satellites for missile target practice — which, coincidentally, China had done earlier that year.

But those guidelines won't prevent accidental collisions; not every spacecraft can dodge the superfast flak. "For the next 50 years", says Johnson, "we're looking at a collision between two large spacecraft every five years or so". That probably won't be enough yet to trigger the Kessler nightmare. On the other hand, a working cleanup scheme seems just as far off.

"It turns out", says Johnson, "to be a very, very difficult thing to do". At the conference researchers discussed several ways of dealing with space junk. A long, electrically conducting wire could be hung from a dead satellite or other large bits of junk, tethering the junk to Earth's magnetic field and dragging it into the atmosphere, where it would burn up. Or a collector satellite, a sort of space garbage truck, could simply scoop junk up, haul it down near the atmosphere, and release it into a death spiral.

For the bits of trash only a few inches across, which are hard to dodge but still damaging, a powerful orbiting laser might work. So might a more passive approach — a giant ball of foam that would sit in space like a spiderweb, sweeping up debris. The foam wouldn't actually capture the debris; like the tether it would simply drain enough energy from the speeding bullets that they'd spiral into the atmosphere. "Of course", Johnson admits, "launching a mile-wide Nerf ball might be difficult". — *Michael D. Lemonick*

The spotlight on pomegranates may shift from seeds to rind.

PHOTO REBECCA HALE, NGM STAFF

Packing a Punch Pomegranates are famous for their jewel-like seeds, whose rich antioxidant stores may help prevent heart disease and certain types of cancer. But some of their most promising health benefits could dwell within their inedible rinds.

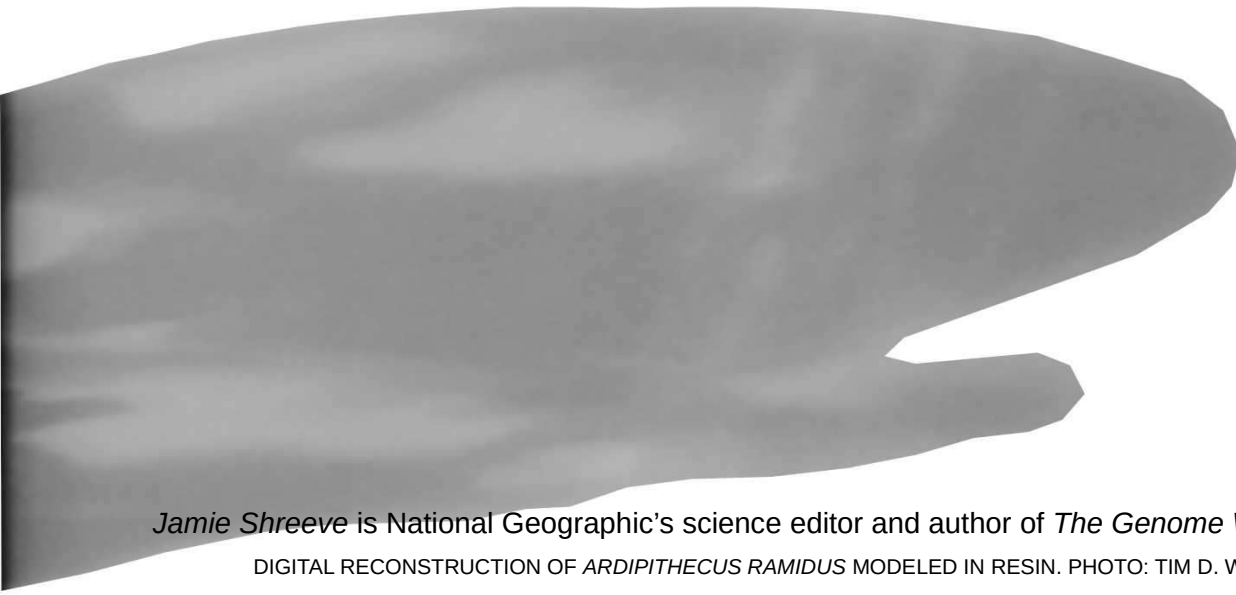
A group of Kingston University researchers in London found that a mixture of pomegranate-rind extract, copper salts, and vitamin C can significantly reduce the growth of some common hospital bacteria. Declan Naughton, head of the study, says the fruit could be a new weapon in the battle against methicillin-resistant *Staphylococcus aureus* (MRSA), which can cause serious skin, blood, and soft-tissue infections. Ironically, the antibiotics used to banish MRSA have spawned even heartier strains — and more people outside of hospitals are catching it.

The high levels of antimicrobials in pomegranate rind that protect the fruit's flesh from harmful bacteria might do the same for humans, says Naughton. An ideal application, with further research, could be an ointment for cuts, abrasions, or surgical wounds. "Once something gets inside your bloodstream, it's difficult to treat", he notes. Another potential benefit: "We don't think it would have major side effects, because we've looked to nature to show the way." — *Cara Birnbaum*

THE EVOLUTIONARY ROAD

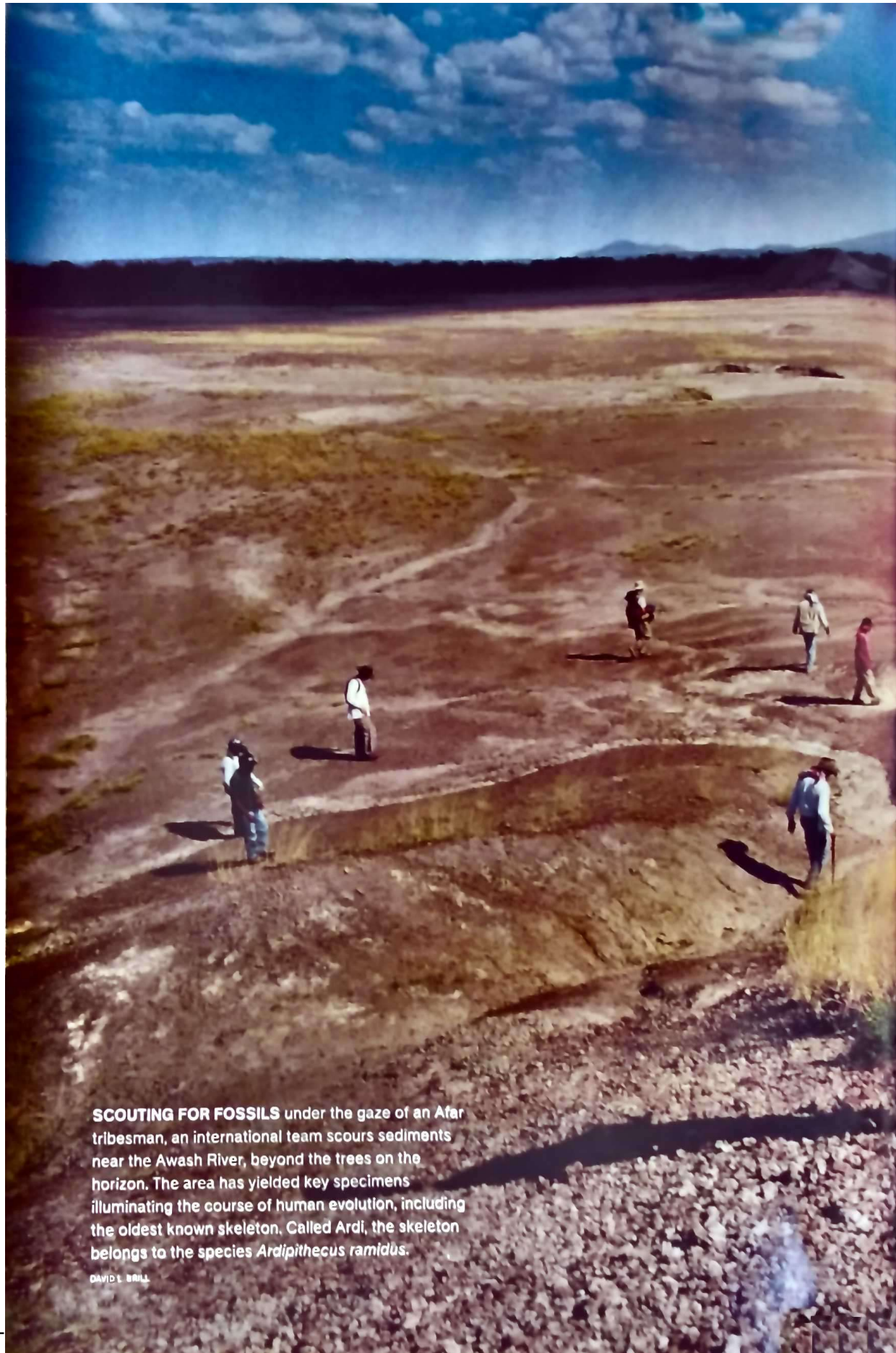
by Jamie Shreeve

The Middle Awash area of Ethiopia is the most persistently occupied place on Earth. Members of our lineage have lived, died, and been buried there for almost six milion years. Now their bones are eroding out of the ground. Step by step they record how a primitive, small-brained primate evolved to conquer a planet. Where better to learn how we became human?



Jamie Shreeve is National Geographic's science editor and author of *The Genome War*.

DIGITAL RECONSTRUCTION OF *ARDIPITHECUS RAMIDUS* MODELED IN RESIN. PHOTO: TIM D. WHITE



SCOUTING FOR FOSSILS under the gaze of an Afar tribesman, an international team scours sediments near the Awash River, beyond the trees on the horizon. The area has yielded key specimens illuminating the course of human evolution, including the oldest known skeleton. Called Ardi, the skeleton belongs to the species *Ardipithecus ramidus*.

DAVID L. BRILL

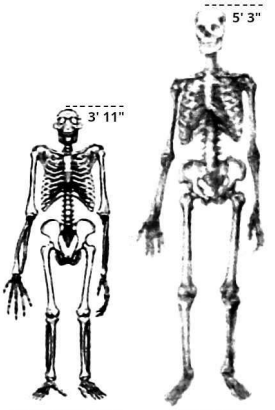
ARDI'S TEETH, some still embedded in her jaws, are more precious than jewels for paleoanthropologist Berhane Asfaw, who cradles them in his hands. The thin enamel, wear patterns, and chemical composition testify to a woodland diet of fruits and nuts.

TIM D. WHITE

ALL ORIGINAL FOSSILS COURTESY
NATIONAL MUSEUM OF ETHIOPIA, ADDIS ABABA

ARDI'S HAND, shown here actual size and recomposed from bones of both her leftt and right hands, is similar in size to a modern human's, despite her small body size (right).

PHOTO: TIM D. WHITE. ART: © J. H. MATTERNES (next page); BRUCE MORSER (RIGHT)



IN THE AFAR DESERT OF ETHIOPIA, THERE ARE A LOT OF WAYS TO DIE. THERE IS DISEASE, OF COURSE. ONE CAN ALSO PERISH FROM WILD ANIMAL ATTACK, snakebite, falling off a cliff, or in a shoot-out between one of the Afar clans and the Issa people across the Awash River to the east.

But life is fragile all over Africa. What is special here is the occasional durability of the deceased's remains. The Afar Basin sits smack atop a widening rip in the Earth's crust. Over time, volcanoes, earthquakes, and the slow accumulation of sediments have conspired to bury bones and then, much later, disgorge them to the surface as fossils. The process is ongoing. In August 2008 a young boy was taken by a crocodile in Yardi Lake, in an area of the Afar known as the Middle Awash. Three months later, Tim White, a paleoanthropologist at the University of California, Berkeley, stood at the lakeshore near where the child had died. Blanketed by lake sediments, he said, the boy's bones had a decent chance of becoming fossils someday too. "People have been dying out here for millions of years", said White. "Occasionally we get lucky and find what's left".

The Middle Awash research project, which White co-directs with his Ethiopian colleagues Berhane Asfaw and Giday WoldeGabriel, announced its greatest good fortune last October: the discovery, 15 years earlier, of the skeleton of a member of our family that had died 4.4 million years ago at a place called Aramis, less than 20 miles north of today's Yardi Lake. Belonging to the species *Ardipithecus ramidus*, the adult female — "Ardi" for short — is more than a million years older than the famous Lucy skeleton and much more informative about one of evolution's holy grails: the nature of the common ancestor we share with chimpanzees. In the mediaphilic field of paleoanthropology, it has become almost a reflex to claim that one's new find "overturns all previous notions" of our origins. Tim White despises such hyperbole. But in Ardi's case, it seems to be true.

Sensational as it is, however, *Ar. ramidus* represents just one moment in our evolutionary journey from an obscure ape to the species that holds in its hands the fate of the planet. There is no single better place on Earth to see how this transformation took place than the Middle Awash. In addition to Aramis, layers there representing 14 other time periods have yielded hominids — members of our exclusive lineage (also called hominins) — from forms even older and more primitive than *Ar. ramidus* to early incarnations of *Homo sapiens*.

White had told me that many of these "windows of time" lie in such close proximity that one could literally walk from one to another in the course of a couple of days. He invited me to join the team in the field so they could prove it. Our plan was to begin in the present at Yardi Lake and walk backward through time, peeling away what makes us human, trait by trait, species by species.

SHARED LAUGHS are part of a day's work in the Middle Awash for project co-leader Tim White and Afar clan chief Ahamed Elema (center). In the discovery process co-leaders Berhane Asfaw (left) and Giday WoldeGabriel (far left, with graduate student Leah Morgan) focus near and far.

Herto: The Ancient Familiar

I RODE INTO THE FIELD WITH TWO dozen scientists and students and six armed guards. Our caravan of 11 vehicles carried enough food and equipment for six weeks. As we threaded through the highlands, sharply terraced fields of sorghum and corn gave way to misted forests. The road was littered with the flotsam of mere history — around a bend the burned hulk of an army armored personnel carrier from the civil war in the 1990s and, farther on, the eroded name "MUSSOLINI" carved in the lintel above a tunnel, a legacy of the Italian occupation of the country in the 1930s.

OUR PLAN WAS TO **WALK BACKWARD THROUGH TIME**, PEELING AWAY THE TRAITS THAT MAKE US HUMAN, TO WHERE WE BEGAN.

From the top of the escarpment we switch-backed down a gargantuan staircase formed as the Arabian continental plate pulled away from Africa beginning some 30 to 25 million years ago, dropping the Afar Basin ever deeper into the rain shadow of the highlands. As we descended, the vegetation grew thinner, the sun more intense. A few hundred yards above the basin floor, we pulled over. Below us the western hills in the foreground fell toward a ragged, fault-scarred plain. On the horizon to the southeast, beyond the green ribbon of the Awash River, the highlands seemed to merge with the cone of the young volcano Ayelu. Below Ayelu was a sliver of silver: Yardi Lake.

Two days later we were walking along its shore — White, Asfaw, and WoldeGabriel, along with two longtime members of the project, geologist Bill Hart of Miami University in Ohio and Ahamed Elema, the leader of the Bouri-Modaitu Afar clan. For a while we followed the lake margin, bright dragonflies flitting about our ankles. It was the perfect setting for making fossils, now as in the past. Animals come to eat, to drink, to kill and be killed. Bones get buried, rescued from decomposition. Over eons, water trickles minerals in, organics out. White — 58 years old, hard and thin as a jackal — poked with his long-handled ice ax at things newly dead. A catfish skeleton left by a fish eagle beneath an acacia tree. The head of a cow, still wearing a leathery mask of dried flesh. "If you want to become a fossil", he said, "you can't do much better than this".

Our first day's walk would take us east across an uplifted finger of land called the Bouri Peninsula, toward the Afar village of Herto. We emerged from the shade of the lake fringe and crossed some low, gray sand dunes. Soon an Afar boy and girl came with their herd of goats to investigate. The Afar are pastoralists, and except for the addition of firearms, their lives today are not substantially different from the way they were 500 years ago. As we walked in the heat among the gently bleating animals, it was easy to imagine historical time rushing backward with every step.

We approached the grass-covered huts and thornbush stockades of Herto. Asfaw, the affable former director of the National Museum of Ethiopia in Addis Ababa, pointed beneath my feet. “Careful where you step”, he said. All around me, pieces of a fossil hippo skull were eroding out of the yellowish, pebbly sand. Nearby rested a teardrop-shaped stone tool, roughly five inches end to end. The Afar people do not make stone tools. We had reached our first window into the past.

In November 1997 the team was surveying where we now stood, just a couple hundred yards from the village, when one of its members spotted a fragment of a hominid skull. Its location was marked with a yellow pin flag, and the team fanned out to search for more pieces. Soon yellow flags sprouted like a field of flowers, concentrated in one spot in particular. Embedded in the sand beneath was what turned out to be a remarkably complete human skull.

While other members of the team excavated these finds, WoldeGabriel, a geologist at Los Alamos National Laboratory in New Mexico, gathered samples — pieces of obsidian and pumice, some as big as tennis balls. Such rocks, spewed in molten form by volcanic eruptions, are gold to a geologist because they can often be dated. The Herto samples were analyzed by Paul Renne of the Berkeley Geochronology Center and in Bill Hart’s lab at Miami University. The results gave an age of 160,000 to 154,000 years for the skull.

The date range was immensely significant. By comparing the DNA of modern people from different regions, geneticists had long argued that the ancestry of all modern people could be traced to a population that lived in Africa between 200,000 and 100,000 years ago. But there was little fossil evidence from this time period to support the genetic model. Now there was Herto. As the broad, heavy-browed male skull emerged from its matrix of sand, it proved the perfect face for the out of Africa theory. It was a very early modern *Homo sapiens* — indeed, Tim White argues it is the earliest member of our own species ever found. The most amazing thing about its high, rounded braincase was the sheer size — at 1,450 cubic centimeters in volume, it's larger than that of an average living human. (A second, less complete skull found at the site may be even larger.) But the fossil’s long face and a smattering of traits in the back of the skull linked it as well to earlier, more primitive forms of *Homo* in Africa, including a 600,000-year-old skull from the Middle Awash found by another team in 1976 at a site called Bodo, across the river.

“One thing we know about the Herto people, they had a taste for meat, especially hippos”, White said, brushing some sand off a hippo skull. Many of the mammal bones collected from Herto bear cut marks from stone tools. It is impossible to say, however, whether the people were hunting the animals or scavenging the kills of other predators. Beach sands with snail shells revealed they were doing the butchering on the banks of a freshwater lake, like Yardi today. But there is no evidence of fire or other sign of occupation, so where they were living is unknown.

Judging by the massive size of Herto man’s brain, he was just as “human” as anyone alive today. Behaviorally, however, there was something crucial missing. The stone tools found at Herto represent a fairly sophisticated technology — but they are not that much different from tools 100,000 years older or, for that matter, 100,000 years younger. There are no pierced beads at Herto, as there are at other African sites some 60,000 years younger. Nor are there carved figurines or other artwork, as one sees in the Upper Paleolithic of Europe, much less any evidence of the bows and arrows, metalwork, agriculture, and all the cultural and technological virtuosity that would follow. By walking back a mere 160,000 years — an eyewink in our evolutionary journey — we had stripped humanity of one of its defining attributes: innovation.

One curious feature of the bones, however, might serve as an augur of the behavioral complexity to come — a whisper of symbol, of meaning. Several days after the discovery of the adult skulls, Berhane Asfaw uncovered another: that of a child, judged to be around six or seven years old. Cut marks on the skull (as well as on the less complete adult cranium) showed that it had been carefully defleshed while the bone was still fresh, in a way that suggested a ritual practice rather than simply cannibalism. The surface of the juvenile skull had been left intact, and it bore a telltale polish, an indication that it had been handled repeatedly. Perhaps the child’s

skull was passed around and worshipped as a relic, possibly for generations, before someone laid it down here at Herto, one last time.

Daka: On Our Side of the Divide

AFTER A QUICK LUNCH, we continued our walk on the opposite side of Herto village, dropping down the eastern slope of the Bouri ridge into a scorching moonscape of gray sandstones, barren and bizarre, pocked with little caves and intricately carved pillars. WoldeGabriel explained how these sediments had been tilted up to the southwest by faulting, then sculpted into these shapes by fierce winds, water, and gravity. The many crevices in the slopes made prime denning sites for hyenas. He pointed to one in the distance, loping away at the sight of us.

We had come to a new window of time, known as the Dakanihylo, or “Daka”, member of the Bouri formation. The Daka sediments are a million years old. Late in December 1997 — a boom year for hominid fossils in the Middle Awash — graduate student Henry Gilbert noticed the top of a cranium eroding out of the Daka sediments. By the end of the day the team had unearthed a hundred-pound bolus of sandstone around the fossil and jacketed it in plaster medical bandages. Back in the museum in Addis Ababa, the surrounding rock was carefully removed with dental picks and porcupine quills, revealing the complete cranial vault of a member of the species called *Homo erectus* — but without a face.

“Maybe a hyena chewed off the face soon after it died”, White said. “It was trying to get at the brain tissue but couldn't. Too bad for us. But at least it left us the vault”.

First discovered in 1891 in Indonesia, *Homo erectus* is one of the best known ancient hominids. In body size and limb proportions it was much like modern people. Its stone-tool culture, known as the Acheulean, was typified in most regions by big, symmetrical hand axes. Elema picked one up to show me: a handsome hunk of black basalt that had been flaked on all sides, missing only its tapered tip. It was a cruder thing than the tools I'd just seen at Herto, but its symmetry nevertheless reflected the key ability to perceive the possibility of form within a chunk of stone and the knapping ability to execute that transformation. Outfitted with those tools and its long legs, *H. erectus* was able to exploit a wide range of habitats and was probably the first hominid to leave Africa, nearly two million years ago, spreading all the way to Southeast Asia.

In the short walk from Herto to Daka, however, something tangible of our humanness had definitely been stripped away too — notably, several hundred cubic centimeters of gray matter. The braincase of the Daka specimen is a thousand cubic centimeters, fairly typical for a *H. erectus* individual and far smaller than Herto or even the intermediate, 600,000-year-old Bodo skull found across the river. And talk about a lack of innovation: Those Acheulean tools made by *H. erectus* remain much the same in the record for over a million years — a span of time one anthropologist has famously described as a period of “almost unimaginable monotony”.

White was more charitable. “The species was tremendously successful, expanding geographically by orders of magnitude. *Erectus* was on our side of a great divide — with an expanded cranium and an ecological niche defined by the use of tools. Go farther back in time, take those things away, and you are looking into an alien world.”

Hata: A Surprise

A SINGLE STEP TOOK US into that stranger place. Below Daka there is a hiccup in the geological succession where the vagaries of rifting and erosion have deleted a hunk of time. With one long stride over this divide we traveled back another 1.5 million years, then walked out above a stark, gully-cut plain, ashy purple in the high afternoon heat.

The purplish beds below us are called Hata, a deeper time window in the Bouri formation. In the mid-1990s a remarkable hat trick of discoveries here opened a vista on one of the most revolutionary transitions in our evolutionary journey. In 1996, the team uncovered antelope, horse, and other mammal bones showing the telltale cut marks of stone tools — at 2.5 million years, one of the earliest signs of tool use.

“The marks on the inside of one antelope jaw showed they cut out the tongue”, White said. “So we not only know they were making tools, we also know what they were doing with them — extracting nutrition from large mammal carcasses”. Curiously, no actual tools were found at the site. Perhaps whoever was doing the butchering kept their tools with them when they left. “I don't think they were occupying this place”, said White. “It was get in and get out”.

Along with these bones came the first intimation of who “they” might be: Just a few feet from where the mammal bones were found, an upper leg bone, some arm bones, and a fragment of lower jaw from a single hominid individual had turned up. The femur was fairly long, an advanced *Homo*-like trait, but the forearm was long too, a more apelike feature.

So far, it was looking like a paleoanthropologist’s dream scenario. By this time, the hominid lineage had forked into two branches. One branch of the genus *Australopithecus* developed specializations for eating tough tubers and other hard foods — huge jaw muscles and massive back teeth. The other branch — hominids with increasingly smaller back teeth, more lightly built, long-legged bodies, and increasingly larger brains — led to us. Bigger brains are useful, of course, but they are also expensive to run. They require high-calorie foods — the kind you get by, say, scavenging the kills of lions and smashing up the bones for their marrow. All that was missing at Hata was a skull that would fit the bill: not as big-brained as *H. erectus* but clearly headed in that direction. Sure enough, in the very next field season team member Yohannes Haile-Selassie, now head of physical anthropology at the Cleveland Museum of Natural History, discovered the first piece of a hominid skull. But it was hardly what the dream scenario predicted.

THIS WAS A CLEVER, TWO-LEGGED PRIMATE EKING OUT AN EXISTENCE AMONG LARGER, FASTER PREDATORS.

Now, while the rest of the group walked up a gully scanning for fossils, Berhane Asfaw and I headed down onto the flat plain to the spot where the skull had been found. Piles of excavated sediment paid testimony to the seven weeks of hard labor it took to remove the fragments. Once it was assembled, the skull did turn out to have some *Homo*-like traits, particularly in the size of the front teeth. But the molars and premolars were huge. And at 450 cubic centimeters, its cranium was no bigger than that of a typical *Australopithecus*. This was not a creature in command of its environment like *H. erectus*. This was a clever, two-legged primate eking out a furtive existence among larger, faster predators and avoiding their jaws long enough to pass its ripening intelligence on to the next generation.

The team chose for it the name *Australopithecus garhi*; *garhi* means “surprise” in the Afar language. *Au. garhi* was certainly in the right place and time to be the immediate ancestor to *Homo*. Whether it is, however, remains to be seen.

“This mystery will be solved soon”, said Asfaw as we hiked back to the cars for the ride to camp. “And it will be solved in the Middle Awash”.

Aramis: Discovery Against All Odds

THE NEXT MORNING I FOUND Asfaw, White, WoldeGabriel, and Elema gathered around some maps, conferring on plans for the day. Our path would necessarily encroach on the territory of a belligerent Afar clan called the Alisera. (“Trigger-happy cowboys”, one researcher called them.) To avoid trouble, we would first pay a diplomatic visit to their village of Adgantole, bringing the six Afar policemen along. Elema would be another advantage: As a district administrator, the Bouri-Modaitu chief also commanded the respect of all the Afar clans in the Middle Awash. After what we hoped would be a friendly chat, the survey team would drive back west toward Bouri-Modaitu territory, dropping a few of us off when we were out of sight of the Village so we could continue our walk into the past undisturbed by the present.

HUNDREDS OF FRAGMENTS of bone, teeth, wood, seeds, and other biological material are sorted by the research crew on a rainy day. When the ground is muddy and streambeds swollen, the crew can't visit the *Ar. ramidus* sites, so they tend to objects they have collected during surface crawls.

Adgantole was a sour-smelling, dusty village beside the Awash River floodplain. The Afar traditionally greet each other with dagu — a flurry of hand kissing and exchange of news. In the other villages we'd visited, people would flock out for dagu. But here just a few people came out to greet us. The clan chief, apparently ill, stayed in his hut. While Elema went in to talk to him, White attempted a little dagu with a dyspeptic-looking young man, who soon walked away.

“A couple of years ago that guy got pissed because I wouldn't hire him”, said White. “He went for his knife and had to be restrained”.

When Elema finished meeting with the chief, we headed back up to the ridge between two stream drainages. Strictly speaking, our next stop on the walk through time should have been a 3.4-million-year-old site called Maka, which had yielded a jaw and some other remains of Australopithecus afarensis. But Maka was on the other side of the river. A shooting war between the Afar and the Issa had rendered the land around the river an uncrossable no-man’s-land — good for wildlife but bad for fossil hunting.

The best known specimen of *Au. afarensis* is Lucy herself, found by Donald Johanson at the eastern African site of Hadar in 1974 and analyzed and published in 1979 by Johanson and Tim White — then only 28 — along with other fossils from Hadar and a site called Laetoli in Tanzania. Dated to 3.2 million years ago, Lucy had a projecting snout and a brain not much bigger than a chimp’s. But her pelvis and limb bones — not to mention actual footprints found preserved in ash at Laetoli — revealed that her species was already bipedal. Some scientists, however, argued that her long, curved fingers, long forearms, and some other traits showed she was also adapted to moving about in the trees, like a chimp. Most scientists assumed that her ancestors must have looked and walked even more like a chimp, swinging in the trees and knuckle walking on the ground. All that was needed were the bones to prove it. They were in for a big surprise.

“We thought Lucy was primitive”, White said, as we drove along the ridge. He let out a big laugh. “We had no idea what primitive meant”.

A few hundred yards farther on, White used his radio to signal the other cars to pull over. Those of us who were time walking got out, and the rest drove on. The previous day we'd walked east toward the river; today we walked southwest, through an eroded expanse of badlands called the Central Awash Complex (CAC). At its heart lay Aramis, home to Ardi herself.

Starting in the early 1990s, Giday WoldeGabriel and colleagues had pieced together the complicated geology of the CAC, and now he gave me a taste. Some 5.2 million years ago, a flood of lava gushed out over an enormous floodplain. Through time, sediments built up atop this base of basalt. Occasional volcanic eruptions would leave thin seams of ash tuffs interlaced among the sediments, like coats of icing between the layers of a great cake. Meanwhile, magma pushing up from beneath the surface tilted the cake up toward the west, reexposing the long-buried sediments and the often datable ash. Our walk took a path into the tilt of the deposits, moving horizontally through space but drilling vertically into time. Unfortunately, through the millennia, the CAC cake has been randomly kicked and flung about by tectonic commotion and chewed by erosion so that slabs of cake and frosting are strewed about in a haphazard mess.

“This isn't like the Grand Canyon”, said WoldeGabriel. “It's a patchwork quilt”.

As we set off down the ridge, WoldeGabriel stopped to chip with his rock hammer at a seam of pale volcanic rock called the Lubaka tuff. (The volcanic tuffs in the Middle Awash have been given Afar animal names; *lubaka* means “lion”.) The Lubaka tuff does not contain minerals that can be dated radiometrically — but not far below it was datable material of a different kind. Throughout the past, the magnetic polarity of the Earth has abruptly flipped and is evident in the orientation of magnetic minerals in some rocks. One of these polarity flip-flops, known to have occurred 4.18 million years ago, left its mark in sediments in the CAC.

Just below this time stamp was our first destination: a bush-pocked flat where a fossil jaw-bone had been found in 1994. It proved to match closely with fossils Meave Leakey and her team had found at two Great Rift Valley sites in Kenya, which she would name *Australopithecus anamensis*. More evidence would turn up in a Middle Awash locale called Asa Issie — a “quilt patch” composed of the same sedimentary cloth, some six miles distant from where we now stood.

All these fossils were a little older and a little more primitive than *Au. afarensis*, but judging from a shinbone found in Kenya and a thigh-bone from Asa Issie, *Au. anamensis* was also a biped. Indeed, there is general agreement — a rarity in paleoanthropology — that the chief difference between the two species is merely the passage of time. In other words, the names represent two arbitrary points in a single evolving lineage, with no clear dividing line between them.

Below the *Au. anamensis* level, the view on hominid evolution in the Middle Awash goes temporarily black. The yellowish green clay we were walking through was laid down between 4.4 and 4.3 million years ago, when this part of the CAC was a lake much like Yardi. Nothing was preserved in the clay but fish. Below this fish layer, however, lay the ultimate prize.

THE FIRST INKLING WAS **AN ENIGMATIC MOLAR WITH JUST ENOUGH DETAIL TO REVEAL IT WAS HOMINID.**

We trudged out onto a cobbled, sunbaked pan, featureless but for a rough semicircle of basalt rocks. The cairn marked the spot where, on December 17, 1992, paleoanthropologist Gen Suwa of the University of Tokyo noticed an enigmatic molar peeking out of the ground. There was just enough detail on it to reveal it was hominid. A couple of days later near the same spot, fossil hunter Alemayehu Asfaw found a piece of a child’s jaw with a first molar tooth.

“That milk molar was like no other hominid baby tooth I'd ever seen, and I'd seen them all”, White told me. “Gen and I just looked at each other. We didn't have to say anything. This was something way more primitive”.

The team set up a perimeter and began sweeping the area clean. WoldeGabriel went to work on the geology. He figured out that the hominid-bearing deposits were sandwiched between two volcanic ash layers, the Gàala ("camel") tuff below and the Daam Aatu ("baboon") tuff above. The dates of these tuffs proved indistinguishable — 4.4 million years for both. This meant the volcanic eruptions had captured between them a focused lens of time — perhaps as little as a thousand years. And everywhere the deposits outcropped along a five-and-a-half-mile arc, there were fossils — monkeys, antelope, rhinos, bears, birds, insects, fossilized wood, and other plant parts, even fossil dung beetle brood balls. They called the place Aramis, the Afar name for a nearby dry streambed.

"At this place, at that time, all the conditions were met", said White, spreading his arms out wide. "Everything was good".

The next year the team began exploring an Aramis exposure less than a mile to the west. More hominid fossils turned up — an unworn upper canine; a pearly, eye-catching molar; more teeth; then an arm bone. But even more important than the hominid bones was the slam dunk evidence for the ecological context the creature had inhabited. For almost a century scientists had assumed that our ancestors first began walking on two legs when they moved out of the forest, where our relatives the apes still live, and onto open grasslands — to move more effectively across long distances, perhaps, or to see above savanna grass. But an overwhelming percentage of the mammal bones at Aramis belonged to woodland-dwelling monkeys and antelope.

Wear patterns on the hominid teeth and analysis of isotopes in their enamel also suggested a generalized diet more fitted to a woodland environment. If indeed the creature was bipedal — so far, the evidence was only indirect — then one of the hallowed tenets of human evolutionary science might be dead. The team would give the new hominid the name *Ardipithecus ramidus*. (Ardi means "ground" or "floor" in Afar, and ramid, "root".)

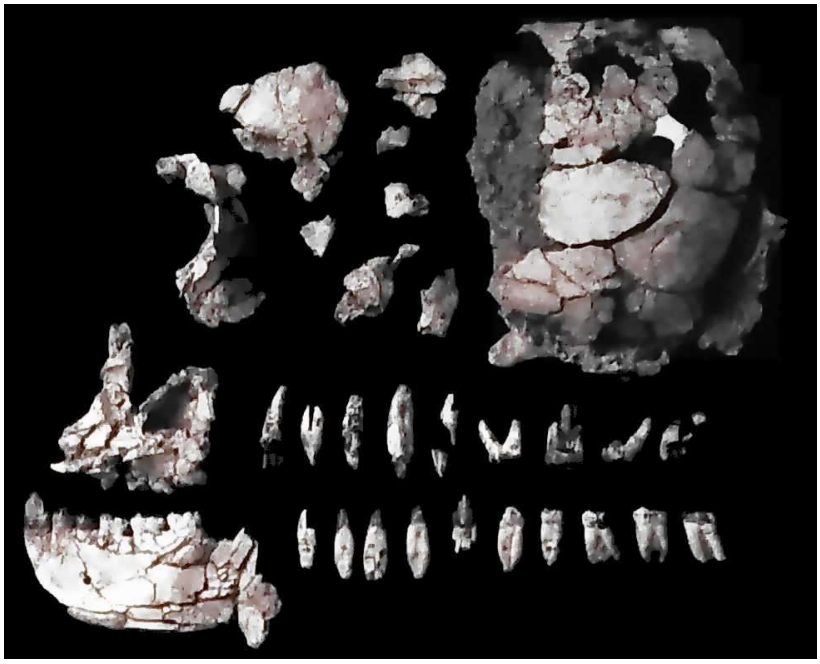
In 1994 the team was eager to return. Normally everyone's energy and nerves are spent on the first day in the field in the frenzied logistics of setting up camp. (White is an exacting "field general", and woe to anyone who pitches his tent before the common area is set up or forgets to bring along a key set of maps.) But with a little light left at the end of that first day, everyone rushed back to the outcrop.

As the sun was setting, Yohannes Haile-Selassie found a hand bone not a stone's throw from where the teeth had been found the previous year. The next day the team began to sieve the loose, sandy silt around the spot — more hand bones and foot bones turned up. Then a sweep of the area produced a tibia. Eventually came the skull and pelvis, both crushed. Indeed, all of the larger bones were in bad shape, virtually turning to powder as they weathered out of the hard-packed sediment. When a bone was found, they doused it repeatedly with hardener, excavated a hunk of sediment around it, and wrapped it all in plaster to keep the fossil safe for the ride back to the museum in Addis Ababa.

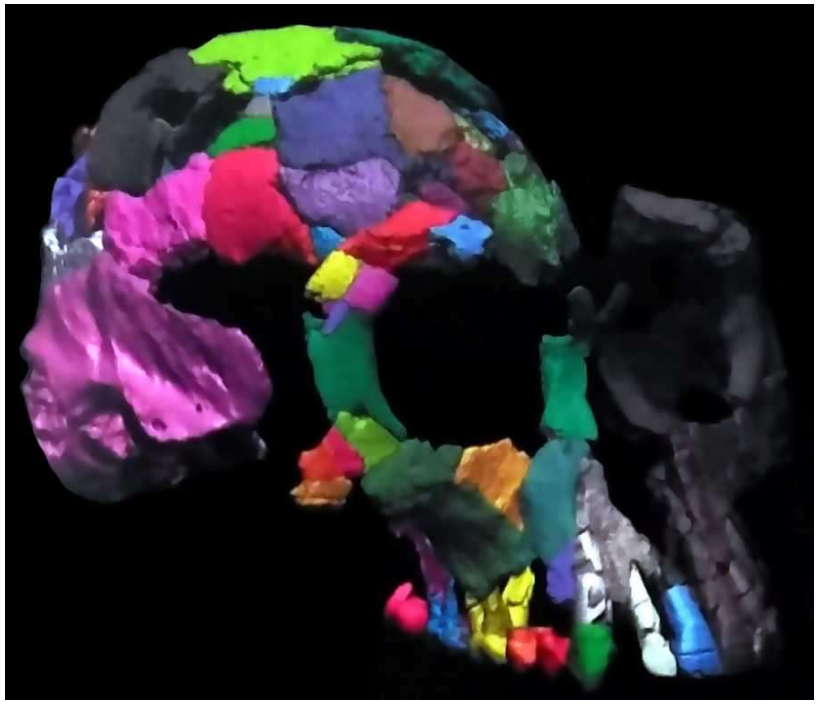
None of the researchers had dared to think it at first, but it was clear they had found the skeleton of a single individual as complete as Lucy but unlike her or anything else that had ever been seen. While most of the other bones at the site showed signs of being ravaged by hyenas after death, the hominid skeleton was miraculously untouched. After the female died, her remains apparently were trampled down into mud by passing hippos or other herbivores and protected from scavengers. After being buried for 4.4 million years, another year or two on the surface would have turned them all to dust.

"It was more than luck", White said. "It was against all odds".

It would take two more years to recover the skeleton, more years to clean and prepare the bones, and still more years to prep and catalog the 6,000 other vertebrate remains from Aramis, conduct isotopic studies of teeth, and parse out the finer points of the geology. Meanwhile, Suwa, a wizard in the new field of virtual anthropology, CT scanned the bones too fragile to handle, creating digital versions that could be analyzed. For 15 years only he, White, and a handful of colleagues had access to the skeleton. Others would have to wait until the team was ready to publish.



RETRIEVED FROM OBLIVION, Ardi's fragmented and crushed skull (above) was too fragile and incomplete to pick apart and reassemble. Instead, Gen Suwa of the University of Tokyo digitally reconstructed a partial skull using micro-computed tomography (CT). From more than 5,000 CT images of the fossils, he pieced together 64 digital fragments. Checking his work against other ancient and modern primates, Suwa rebuilt a virtual skull and made a mirror image of part of the face to create its missing left side (brown section). He assigned colors to the rest of the pieces to differentiate them.



On the ride up to Adgantole, we stopped at the Ardi skeleton site itself, on a flat wash below the road, about the size of a tennis court. The excavation was covered by a large mound of stones. The place was silent now, but I could imagine the shouts of excitement as each bone — 125 of them in all — peeked out from the earth or later emerged from its plaster jacket in the museum.

“There were no eureka moments”, White told me sternly, later, when he was able to talk more freely about the skeleton. Then he described half a dozen of them. One came when he removed the plaster around a little foot bone called the medial cuneiform, which articulates with the base of the big toe. In humans and all other hominids, the joint surface of this bone is oriented so that the big toe lines up with the others, providing a strong “toe off” for an effective bipedal stride. In apes the joint surface points in a different direction, so that the big toe can pull away from, and grasp against, the other toes to grip on to tree limbs. In this key feature, Ardi was like an ape. Yet in other respects her foot was nothing like an ape at all, bearing characteristics that would enable her to walk upright.

Everywhere the scientists looked, they found a similarly bizarre mosaic of traits: some very primitive, others advanced and exclusive to hominids. Ardi wasn't just another biped, or just another quadruped. Ardi was *both*.

THE MISSING LINK IS A MISCONCEPTION THAT HAS PLAGUED EVOLUTIONARY THOUGHT FROM THE BEGINNING

I asked White whether Ardi’s transitional form might justify calling *Ar. ramidus* a “missing link”. He bristled at the very question.

“That term is wrong in so many ways, it's hard to know where to begin”, he said. “Worst of all is the implication that at some point there existed something halfway between a chimp and a human. That's a popular misconception that has plagued evolutionary thought from the beginning, and one Ardi should bury, once and for all”.

If the Middle Awash team is right in its interpretation, *Ar. ramidus* is indeed nothing at all like a modern chimp or gorilla. (See “The Birth of Bipedalism”.) Of course apes and humans derive from a common ancestor. But their lineages have been evolving in separate, and quite different, directions ever since.

Beyond: The Last Common Ancestor

BACK IN THE MIDDLE AWASH, I still had a million years to walk before supper. From Aramis we hiked across a cobbled plain until we reached an overlook where more than a hundred square miles of the study area sprawled under an immense blue sky. Below us dark, gullied ridges held another half million years of sediments. Beyond them was the basalt, laid down when this vast plain was swamped in lava, 5.2 million years ago. To the left was the low hump of a relict volcano called Dulu Ali and, beyond, the Bouri Peninsula and Yardi Lake, where we'd started the day before. This vantage point seemed like a good place to look back up the evolutionary road that led Ardi to us.

“What finding Ardi allows us to do is to think of human evolution as three stages of assembly”, White said. “But the boundaries between even these stages are arbitrary, a matter of convenience”. The first stage is best represented by *Ardipithecus* — “ground zero” — a primitive biped with one part of its foot in the past and one in the future, its male canines already reduced and “feminized” in shape, its habitat restricted to woodlands. Then came more than two million years of *Australopithecus* — still small-brained but fully bipedal, no longer restricted to woodlands, and with a geographic range extending fully 1,500 miles west of the rift to Chad and south to the Transvaal of South Africa. A tremendously successful hominid stage, in time and in space.

Did *Australopithecus* evolve from *Ardipithecus*? Hard to say. In the Middle Awash, there's that hominid-free fish layer drawing a curtain between them. Until more evidence is found, there or elsewhere, it is not clear whether Ardi is Lucy's "mother" or a maiden aunt who went extinct without issue.

But White would say there's a better question to ask: Would it be possible to derive *Australopithecus* from *Ardipithecus* parts? Some scientists find this to be too much of a stretch. White disagrees. We now know from genetic studies that small alterations in the regulation of genes can have major anatomical consequences in a short amount of time. If it proved a major advantage to walk upright more effectively, White maintains, it wouldn't take too many millennia for natural selection to evolve a big toe in line with the others and otherwise rejigger the skeletal design.

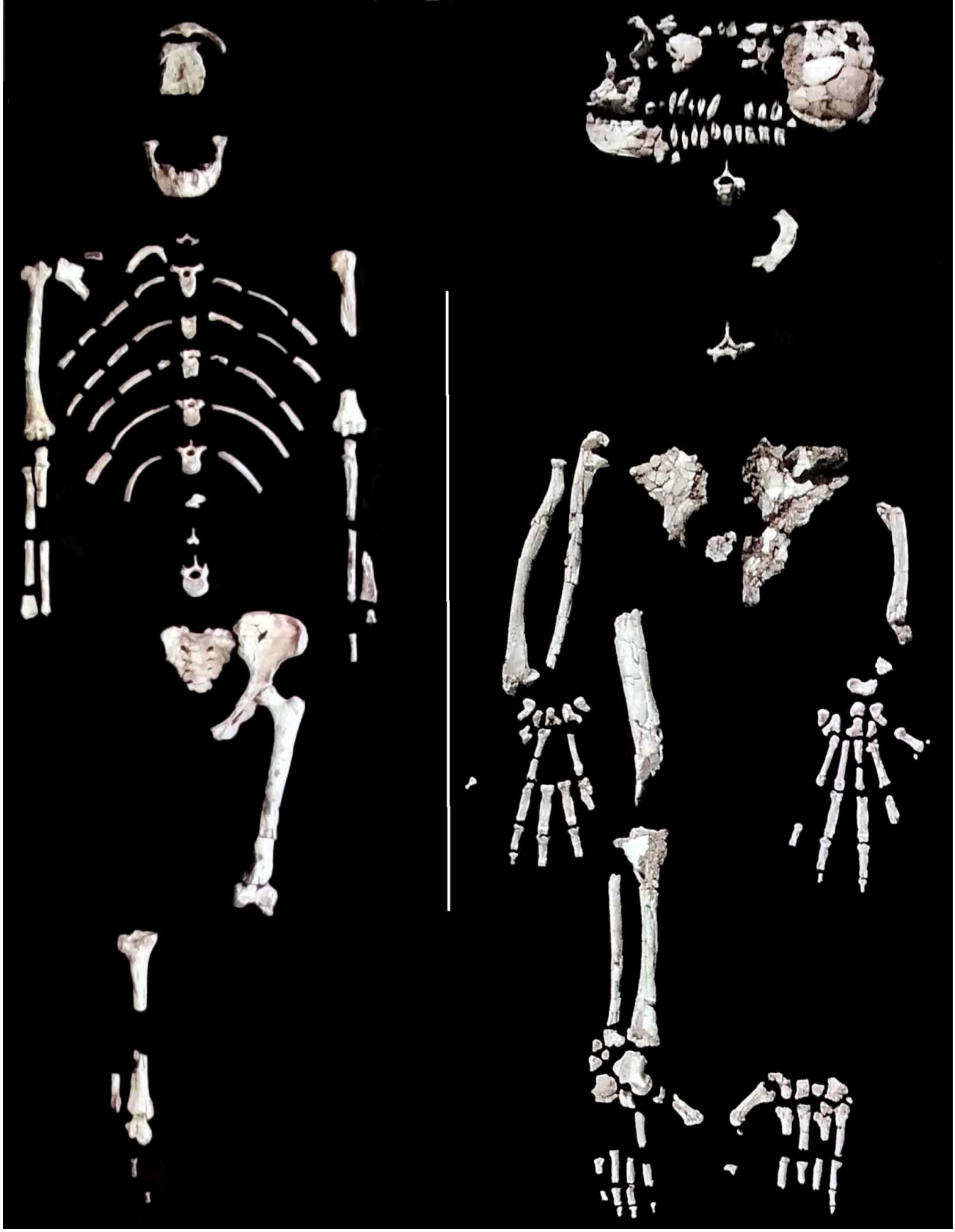
The same rules apply to the transition from *Australopithecus* to the third stage of our assembly. Start flirting with higher calorie foods, nourish the further growth of the brain that helped you to figure out how to get at them in the first place, and presto — Daka, Bodo, Herto, us. Of course, fossils from other places in Ethiopia and beyond also light up the human evolutionary road, often more brightly than those from the Middle Awash. But its long record of change dramatically demonstrates that evolution is a matter of building on what had been built before.

"A car assembly line is an apt analogy", White said. "Bipedality is the frame. Technology is the body. Language is the engine, dropped in toward the end ofthe assembly; iPhones are the hood ornaments".

From that overlook in the Awash, we could also look west, farther into the past to the foothills of the escarpment, forming the western margin of the study area. Fragmentary hominid bones have been found there too, extending back to 5.8 million years. Collected over four years by Yohannes Haile-Selassie, they have been given the name *Ardipithecus kadabba*. Most scientists believe *Ar. kadabba* to be a "chronospecies" of *Ar. ramidus*, bearing the same relationship to it that *Au. anamensis* bears to *Au. afarensis*: an earlier version of the same basic plan. White and his colleagues would also include in this continuum two even older finds — intriguing six-million-year-old broken thigh bones from Kenya called *Orrorin tugenensis* and a spectacular, if enigmatic, skull from Chad named *Sahelanthropus tchadensis*, tentatively dated at close to seven million years old.

However ancient these isolated specimens are, it is *Ar. ramidus* that, for now at least, gives us the best insight into what lies at the very base of the human lineage: that last common ancestor we share with the chimpanzees. A few months after I returned from the Awash, I asked White what he thought the last common ancestor would have looked like. Nothing like a "missing link" to a chimpanzee, of course. His best guess was that it would resemble Ardi herself, though without the suite of traits that allowed her to walk on two legs, however ineffectively. But this was only a prediction. And if there was one thing I'd learned in the Middle Awash, it was not to trust predictions.

"If you really want to know what something was like, there's only one way", White said. "Go out and find it".

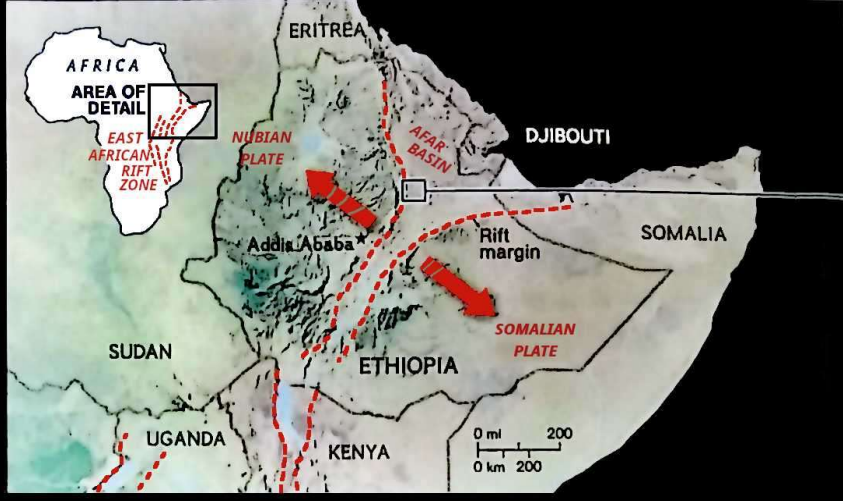


LUCY AND ARDI (left and right respectively) lived more than a million years apart. With the discovery of Ardi, 3.2-million-year-old fosill Lucy is no longer the oldest hominid skeleton known. Found in 1974 some 40 miles north of the Middle Awash, Lucy's pelvis and limbs testify to a fully bipedal gait — an evolutionary breakthrough Ardi had yet to make.

DAVID L. BRILL (ABOVE, LEFT); TIM D. WHITE

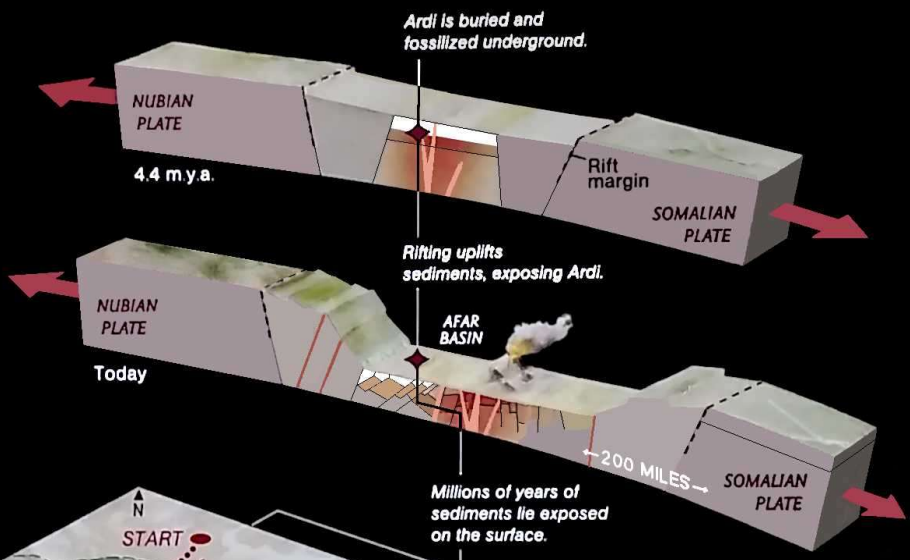
TIME TRAVEL

The Great Rift Valley of eastern Africa is uniquely suited to create and preserve fossils. Beneath the surface, continental plates are pulling apart (map, right). Millions of years of tectonic activity and sedimentation have buried, preserved, and brought back to the surface the remains of hominids that once inhabited the region. Associated volcanic material can often be dated.



ARDI'S JOURNEY

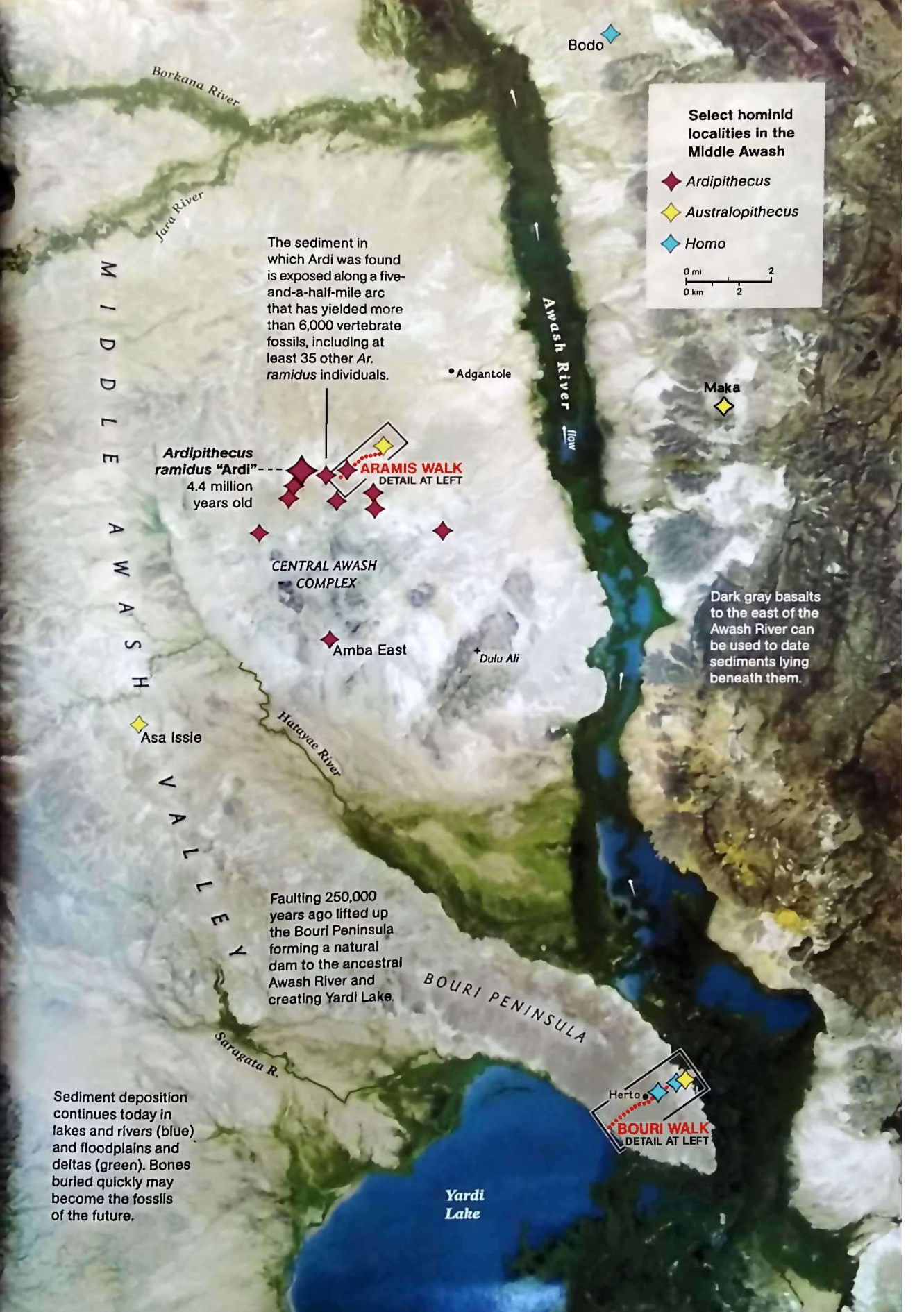
After Ardi died, her bones were quickly buried. Minerals began to replace organic materials. As rifting continued, the Afar Basin sank and filled with sediments. Faulting, uplifting, and erosion conspired to reexpose her fossilized bones.

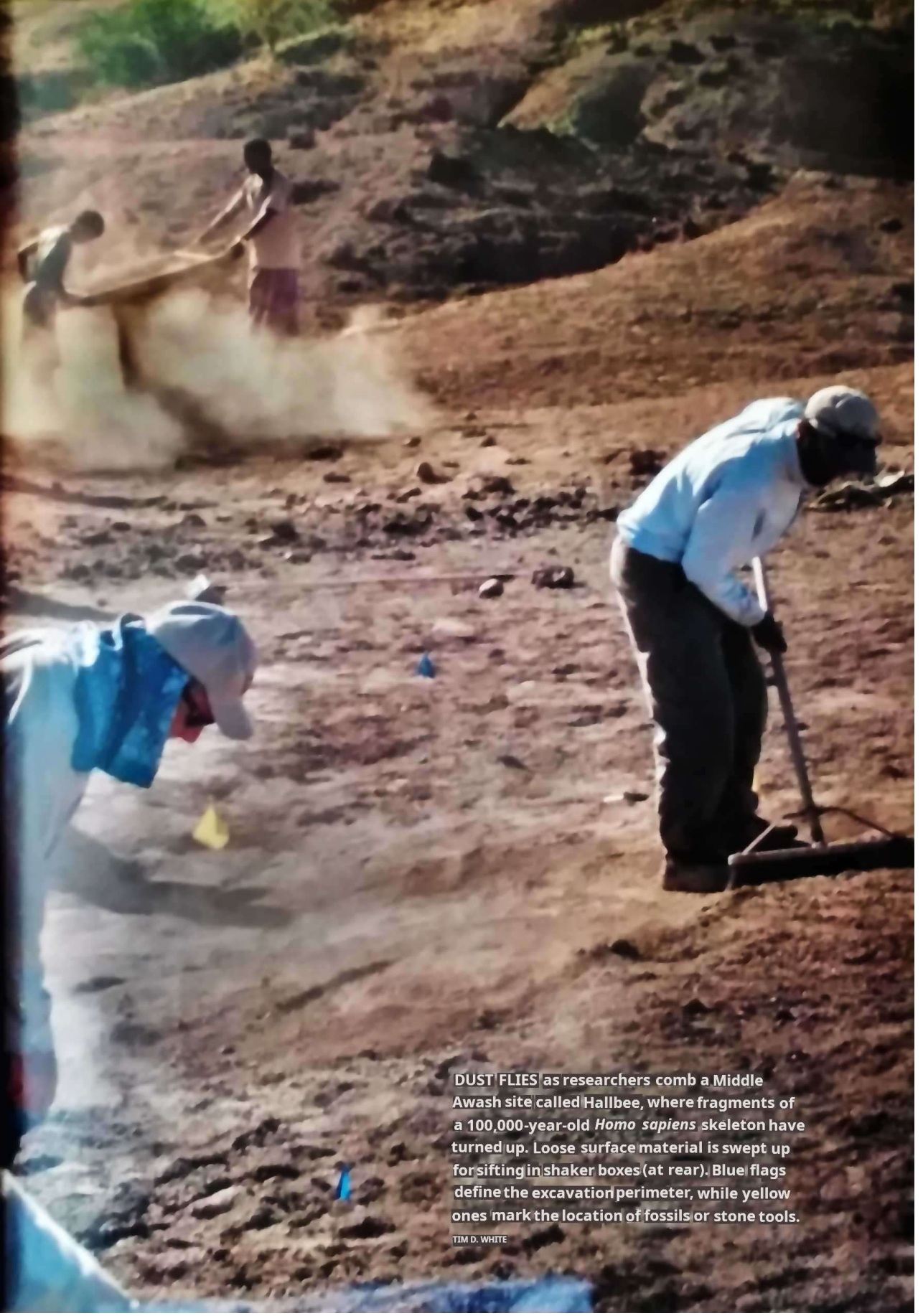


AUTHOR'S ROUTE

Jamie Shreeve spent two days walking and covered about five million years.

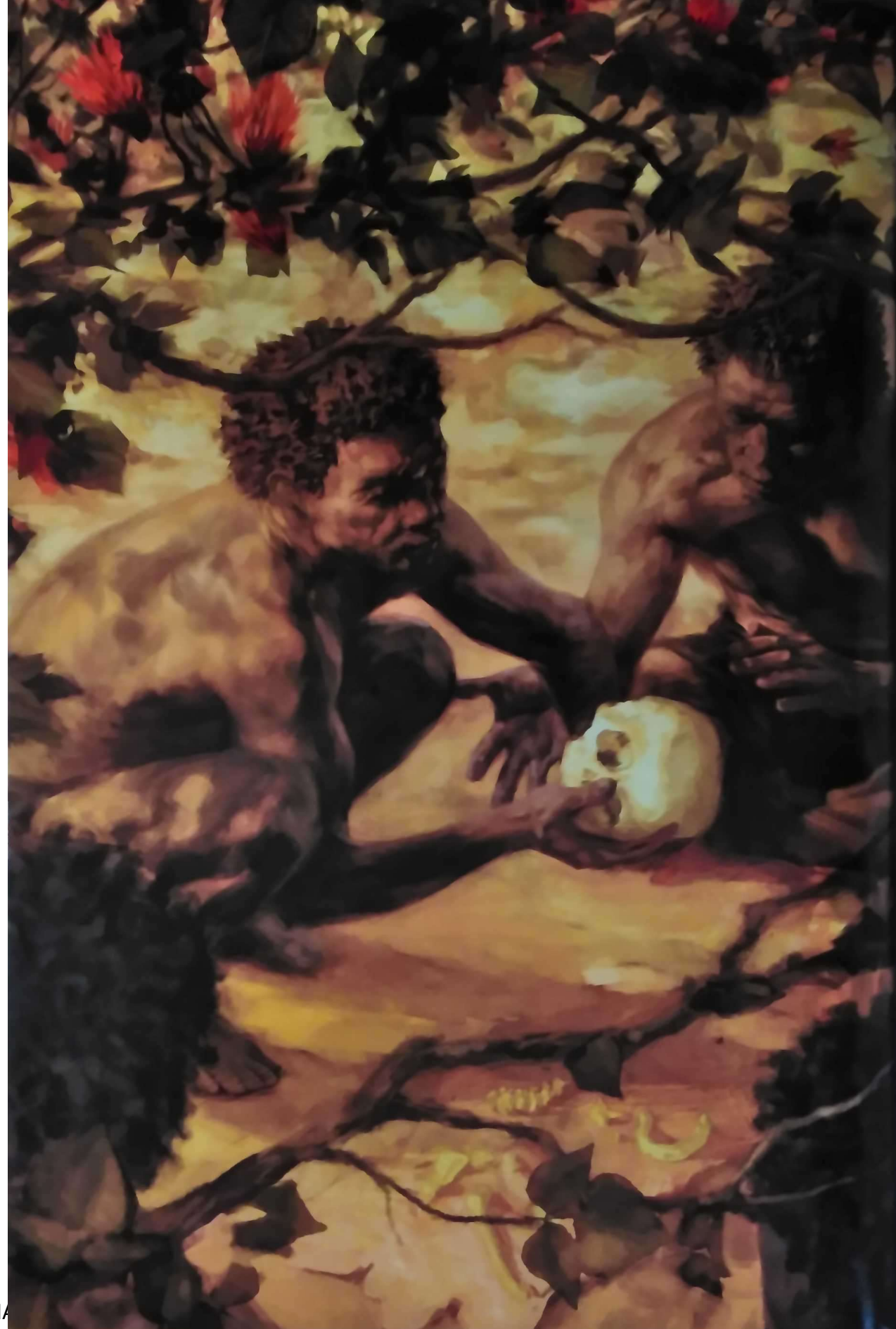
WILLIAM E. MCNULTY, NGM STAFF
ART: GARY HINCKS
SOURCES: GIDAY WOLDEGABRIEL, LOS ALAMOS NATIONAL LABORATORY AND TIM D. WHITE, UNIVERSITY OF CALIFORNIA, BERKELEY
SATELLITE IMAGE: NASA/JPL


Bodo
Borkana River
Jara River
Select hominid localities in the Middle Awash
Ardipithecus
Australopithecus
Homo
0 mi 2
0 km 2
The sediment in which Ardi was found is exposed along a five-and-a-half-mile arc that has yielded more than 6,000 vertebrate fossils, including at least 35 other Ar. ramidus individuals.
Adgantole
Awash River
flow
Maka
MIDDLE AWASH VALLEY
Ardipithecus ramidus "Ardi"
4.4 million years old
ARAMIS WALK
DETAIL AT LEFT
CENTRAL AWASH COMPLEX
Amba East
Dulu Ali
Dark gray basalts to the east of the Awash River can be used to date sediments lying beneath them.
Asa Issie
Hatayae River
Faulting 250,000 years ago lifted up the Bouri Peninsula forming a natural dam to the ancestral Awash River and creating Yardi Lake.
BOURI PENINSULA
Saragata R.
Herto
BOURI WALK
DETAIL AT LEFT
Sediment deposition continues today in lakes and rivers (blue) and floodplains and deltas (green). Bones buried quickly may become the fossils of the future.
Yardi Lake



DUST FLIES as researchers comb a Middle Awash site called Hallbee, where fragments of a 100,000-year-old *Homo sapiens* skeleton have turned up. Loose surface material is swept up for sifting in shaker boxes (at rear). Blue flags define the excavation perimeter, while yellow ones mark the location of fossils or stone tools.

TIM D. WHITE



160,000 YEARS AGO

A Sign of Ritual

BOURI-HERTO, ETHOPIA The skull of a child that was defleshed after death may be a remnant of an early human ritual (artist's conception, left). Dating to between 160,000 and 154,000 years ago, the skull and those of two adult early *Homo sapiens* were found near the village of Herto on the Bouri Peninsula. The polished surface of the child's skull suggests repeated handling: a treasured relic whose meaning we will never know.

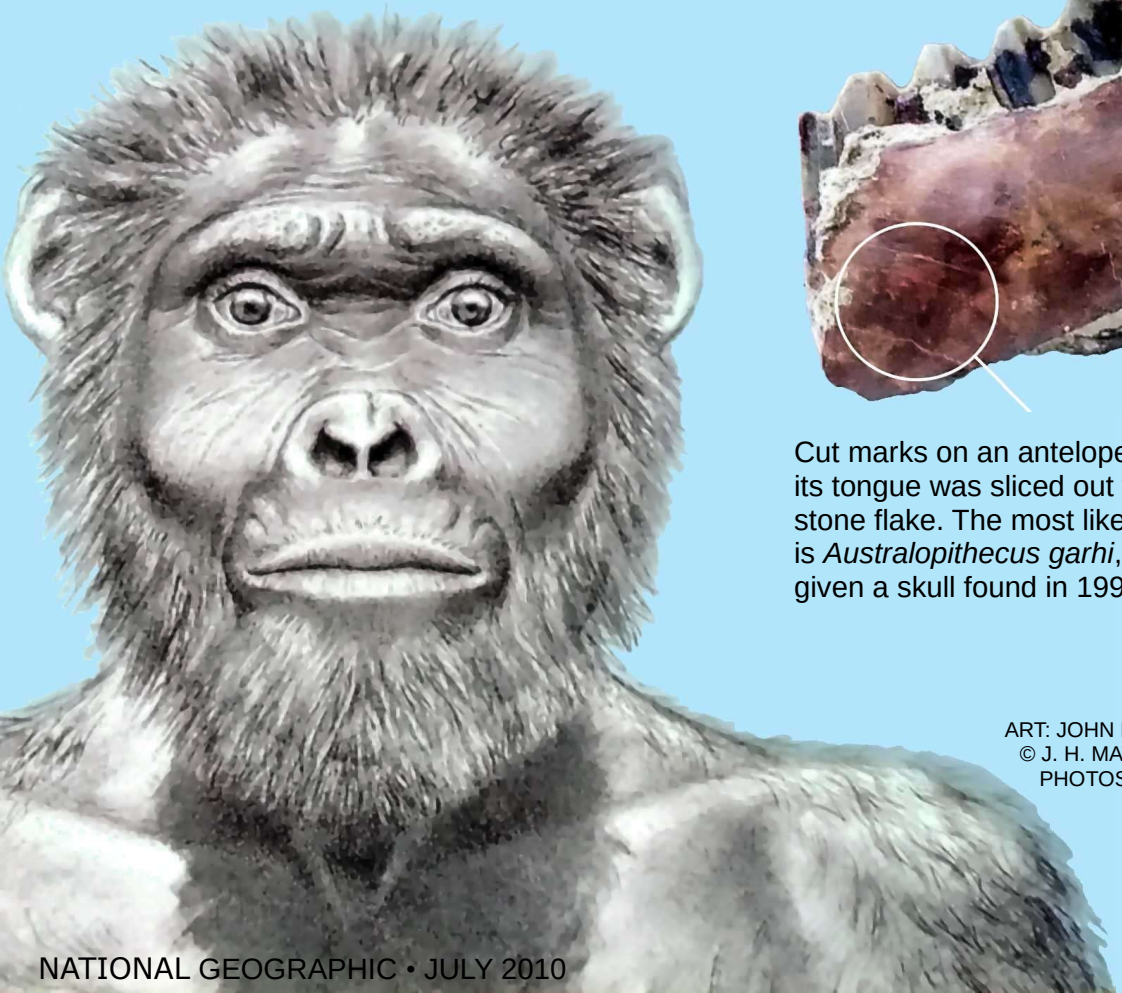
A large-brained, early *Homo sapiens* skull found in 1997 (above) reveals the imposing face of Herto man. Large cleavers (top right, 7.5 inches long) and other flaked stone tools were used to butcher hippos.

ART: JOHN FOSTER (LEFT);
© J. H. MATTERNES (RIGHT)
PHOTOS: DAVID L. BRILL

2.5 MILLION YEARS AGO

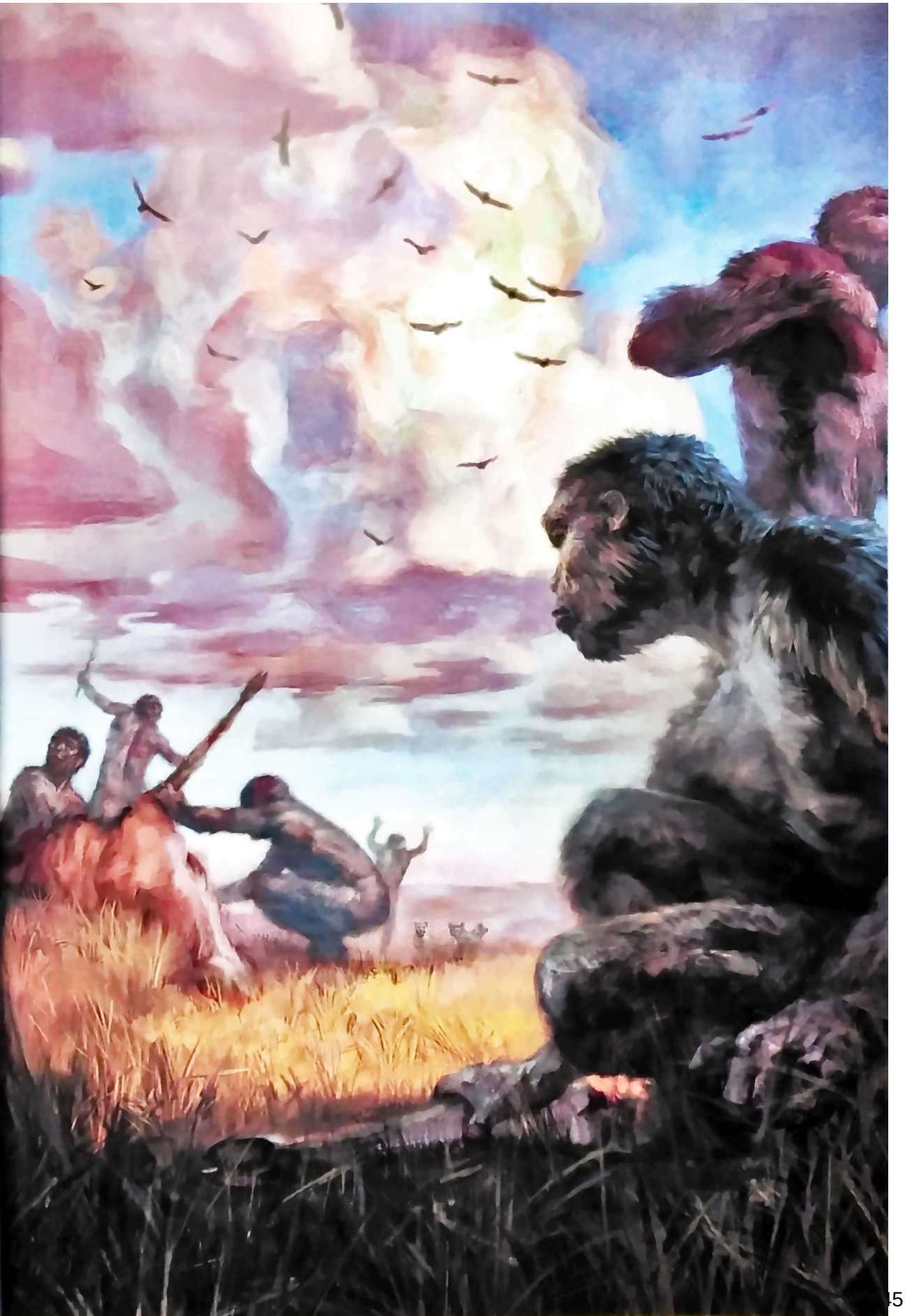
The Emergence of Tools

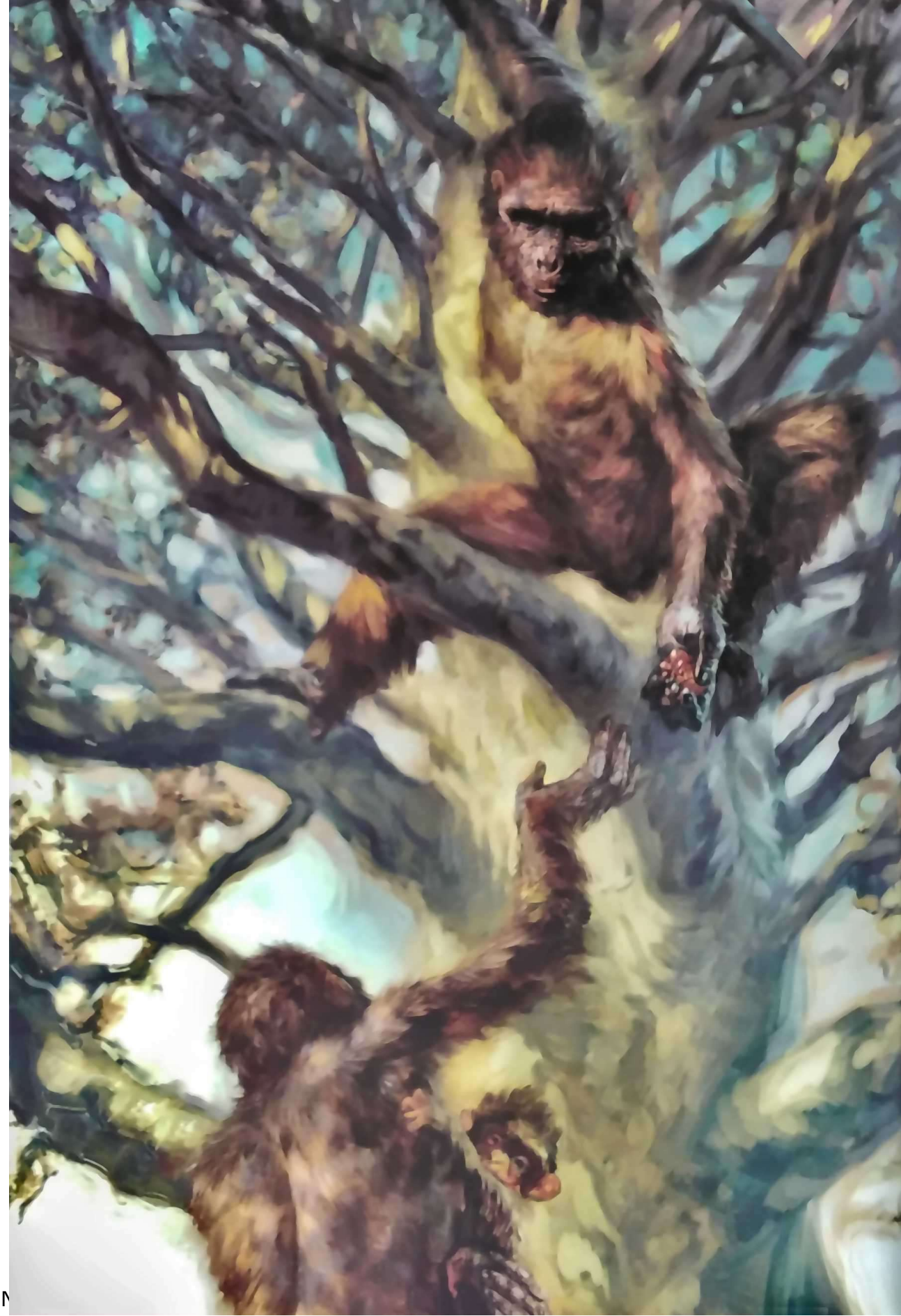
BOURI-HATA, ETHIOPIA On open ground, our australopithecine ancestors were more likely to be prey for lions and hyenas than competitors for their kills. Then the game changed. Crude stone tools first appear 2.6 million years ago. Some 100,000 years later, hominids on the Bouri Peninsula used tools to scavenge meat and marrow from large mammal carcasses (artist's conception, right). Such high-energy foods would have been the perfect diet for evolving the metabolically expensive bigger brains characteristic of later *Homo*. The scavengers at Hata were only trying to feed themselves and stay alive another day. But up the evolutionary road, this expansion of diet may have had enormous consequences.



Cut marks on an antelope jaw indicate its tongue was sliced out with a sharp stone flake. The most likely toolmaker is *Australopithecus garhi*, the name given a skull found in 1997 (top left).

ART: JOHN FOSTER (RIGHT)
© J. H. MATTERNES (LEFT)
PHOTOS: DAVID L. BRILL





The Birth of Bipedalism

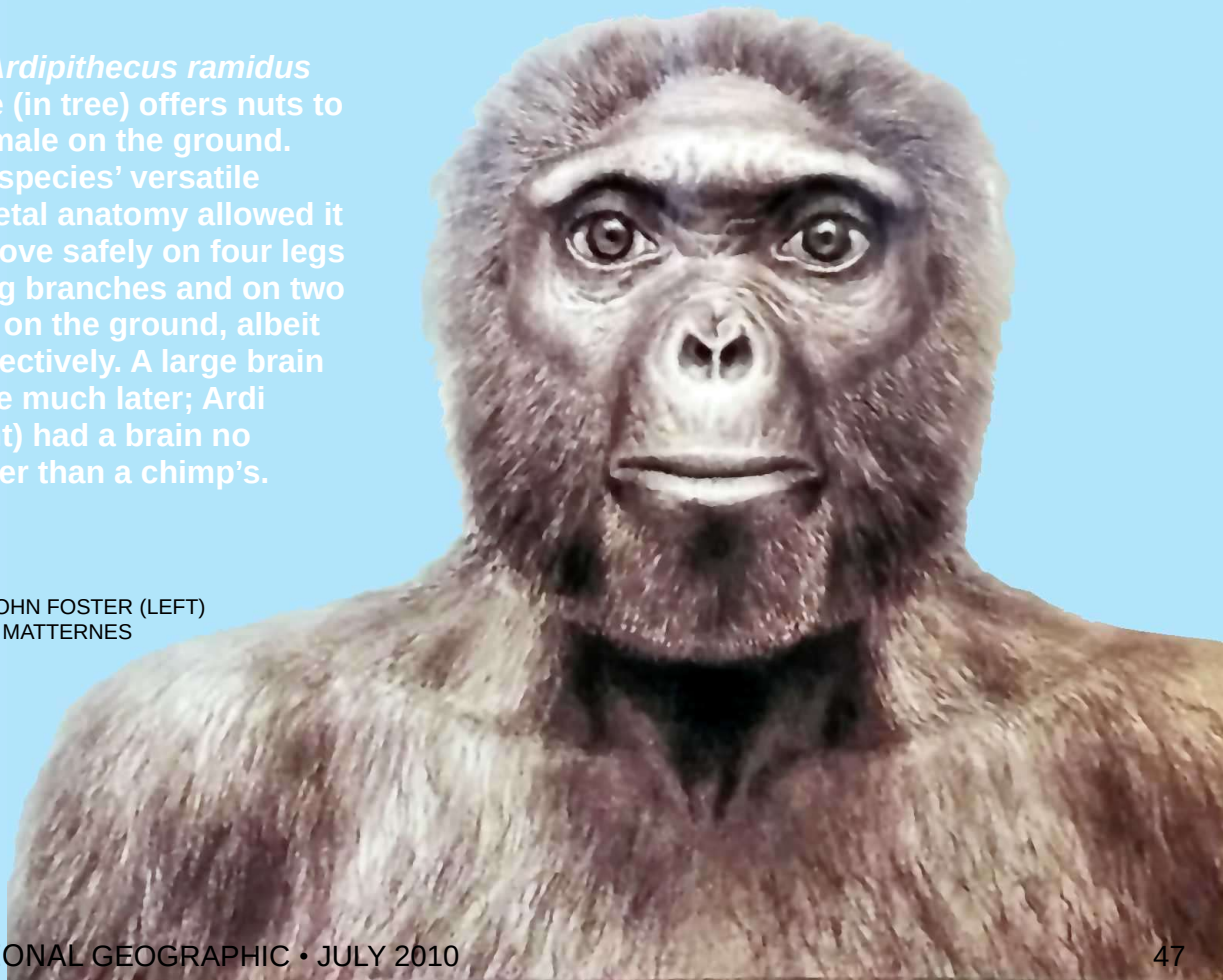
ARAMIS, ETHIOPIA

Owen Lovejoy's first glimpse of the female who would preoccupy him for the next 14 years left him cold. It was 1995, and Lovejoy, a comparative anatomist at Kent State University in Ohio, was getting a privileged peek at the freshly excavated skeleton of *Ardipithecus ramidus* in the National Museum of Ethiopia in Addis Ababa. Some of the bones were badly squashed.

"My first thought was, Why did they bring us over here to look at roadkill?" Lovejoy recalls. "It took about ten minutes to realize that all the important parts were there. My second thought was, Jesus Christ, who could have predicted *this*?"

Over the years, as Ardi's bones were freed from their rock-hard matrix and reconstructed, Lovejoy's astonishment would only grow. It had long been assumed that the further one probed into the human evolutionary past, the more our ancestors would look like our closest living relatives, the chimpanzees. At 4.4 million years, Ardi was over a million years older than the famous Lucy skeleton, which Lovejoy had also analyzed. *Ar. ramidus* didn't look like Lucy — but she didn't look like a chimpanzee either. Instead, she possessed a weird combination of way primitive traits seen before only in monkeys and extinct apes from the Miocene epoch and traits seen only in our own hominid lineage.

Consider Ardi's toot. All later hominids including Lucy, have a big toe that lines up with the other toes, helping to provide the propulsive force in upright wearing, long the hallmark of our



An *Ardipithecus ramidus* male (in tree) offers nuts to a female on the ground. The species' versatile skeletal anatomy allowed it to move safely on four legs along branches and on two legs on the ground, albeit ineffectively. A large brain came much later; Ardi (right) had a brain no bigger than a chimp's.

ART: JOHN FOSTER (LEFT)
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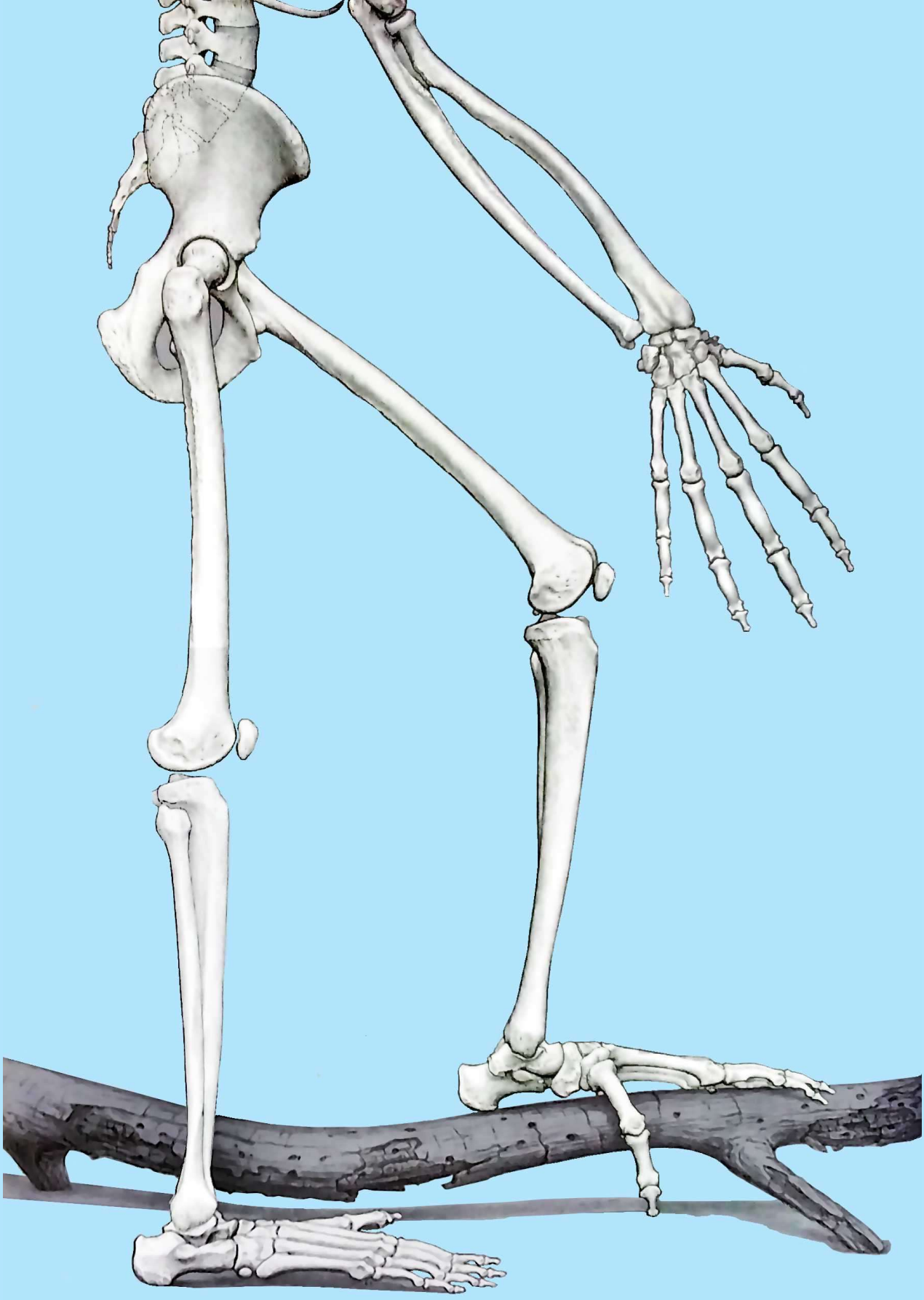
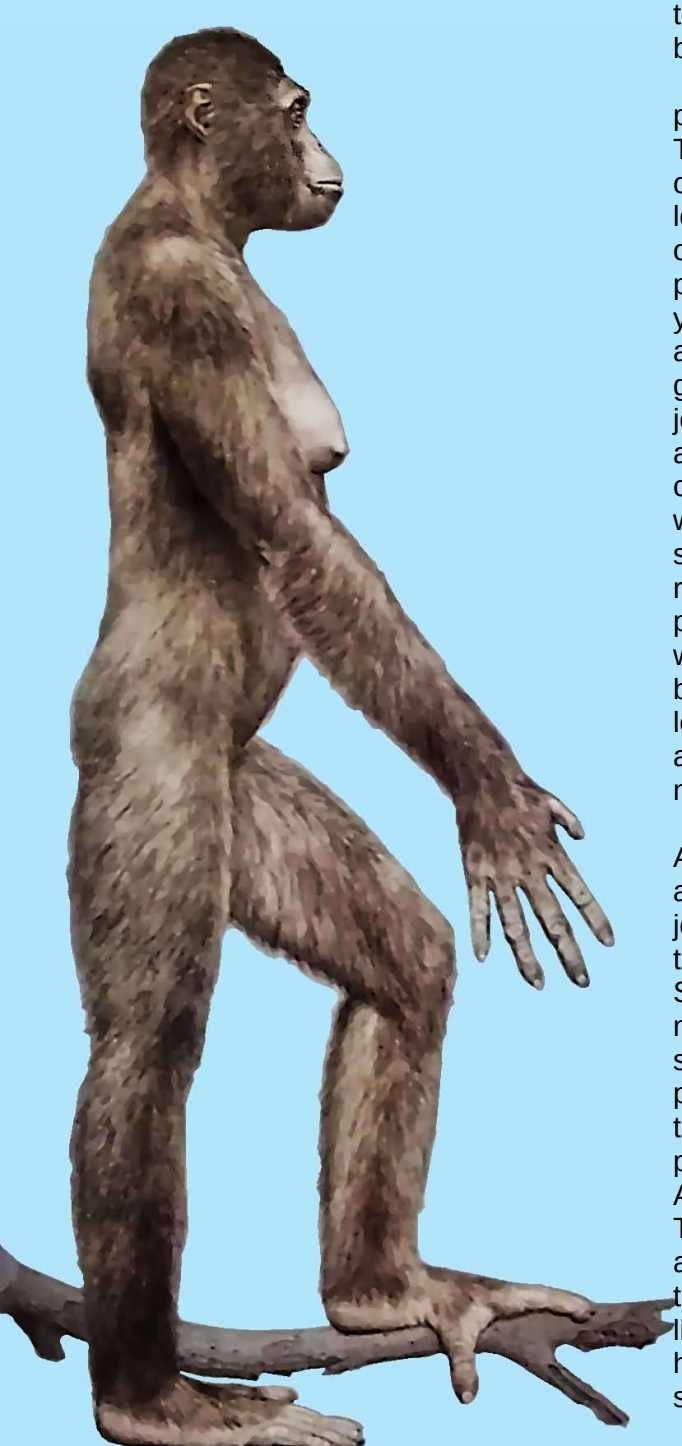


ART: © J. H. MATTERNES

Ardi's foot features an opposable big toe: well suited for grasping branches but a poor arrangement for push off in a bipedal stride, as in later hominids. According to her discoverers, the other four toes carried that load. Moving in the trees was aided by long fingers and highly flexible wrists.



lineage. Ardi's big toe instead splayed out to the side, like those of apes — the better to grasp on to limbs when clambering about in the trees. Yet Ardi's foot also contains a small bone called the os peroneum — retained in the hominid lineage from ancient apes and monkeys but almost never seen in chimps and gorillas — that keeps the bottom of the foot more rigid. Lovejoy and his colleagues believe that this rigidity enabled *Ar. ramidus* to walk upright on the groun, using its four aligned toes to provide the levering 'toe off' that propels a bipedal stride.

Ardi's pelvis also bears witness to a primitive primate caught in the act of becoming human. The human pelvis has undergone a major overhaul to adapt it tor upright walking — a locomotor juggling act requiring one limb or the other to be suspended in the air while the other pushes forward. As far back as Lucy, 3.2 million years ago, our hip bones had become broader and shorter to enlarge attachment areas for gtuteal muscles that stabilize the supporting hip joint. In contrast, chimp pelvises are narrow and long and provide more rigid support for climbing but force chimps to lurch side to side when walking upright. Ardi's upper pelvis is short and broad and shows other features rarely seen except in hominids, such as a protrusion on the inside edge of the pelvis where bone was added during development to bolster support for a bipedal stride. Yet the lower pelvis is thoroughly apelike, with attachments for massive hind-limb muscles needed for effective climbing.

Then there is Ardi's surprising hand. Living African apes have long fingers and palms adapted to arboreal climbing and strong, stiff joints in their hands to support their weight on their knuckles when they walk on the ground. Since this knuckle-walking adaptation is seen not only in chimps but also in gorillas, which separated from our lineage even farther in the past, it has long been thought that it represents the primitive condition that our own ancestors passed through on their way to walking upright. Ardi's hand utterly confounds that assumption. Though her fingers are long, her palm is short and very flexible. This would have allowed her to walk on her palms on top of tree limbs, more like a monkey than any living ape, as well as hold on to branches well behind her head as she moved along limbs.

PHOTO: DAVID L. BRILL; ART: © J. H. MATTERNES

Owen Lovejoy (in white shirt) confers with Bruce Latimer about Ardi's pelvis and hips, which would have enabled both bipedal walking and powerful climbing in the trees. In an artist's reconstruction (far right), Ardi's lower lumbar vertebrae are not attached by ligaments to her hip blades (as they are in modern apes). This primitive skeletal arrangement was inherited from ancient apes and repurposed in hominids for upright walking.

Combined with the other very primitive traits in *Ar. ramidus*, this monkey-like hand holds enormous repercussions for understanding our origins. If Ardi's discoverers are right, our ancestors never passed through a chimp-like, knuckle-walking phase on their way to walking upright. To argue that they did so would require that very early in our lineage we developed a chimp-like tool kit of adaptations — and then lost them all again and reverted to the primitive condition by the time *Ar. ramidus* was walking around. This is highly unlikely.

Still, given all the extremely primitive traits, some researchers argue that *Ar. ramidus* isn't really a hominid in the first place. Terry Harrison of New York University, for instance, points out that there was a tremendous diversity of ape species throughout most of Africa and Eurasia in the Miocene epoch, between 23 and 5 million years ago. "Perhaps it was just one of those apes running around, rather than the one that gave rise to hominins", says Harrison. In response, Lovejoy points to more than two dozen distinct traits that link *Ar. ramidus* exclusively to later hominids — which, if what Harrison postulates is right, would all have somehow ended up together by coincidence in an extinct ape that had nothing to do with us.

Even if *Ar. ramidus* is a hominid, was it really bipedal? Before Ardi was found, such a question would have been unthinkable. Among higher primates, only hominids are bipedal, ergo all hominids must be bipedal. But people assumed all hominids must have enlarged brains too — until the first little-brained australopithecine was found in 1924. Many scientists simply don't see how Ardi would have gotten around very well on two feet, especially with that widely divergent big toe.

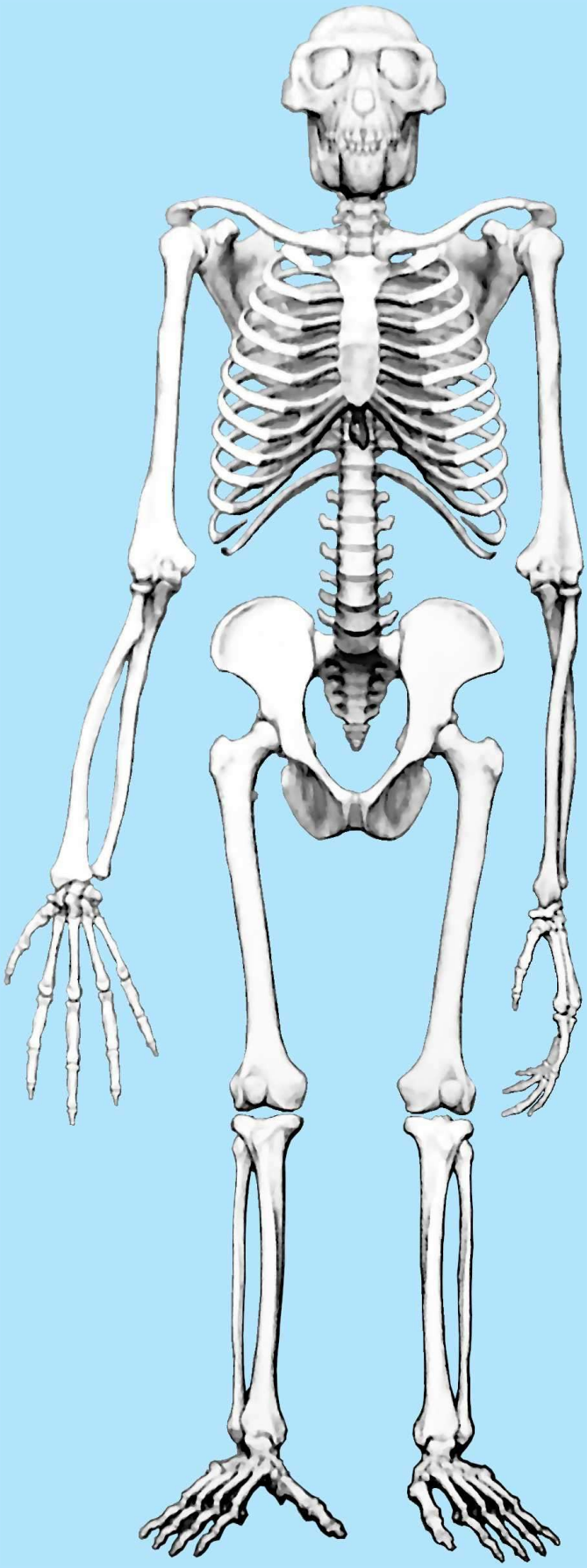
"That ain't the toot of a biped!" comments William Jungers, an evolutionary morphologist at Stony Brook University. "Ardi has one of the most divergent big toes you can imagine. How did she get up in the trees without vertically climbing the trunks? Did she fly up there?" Why, asks Jungers, would an animal fully adapted to quadrupedal movement in trees elect to walk bipedally on the ground?

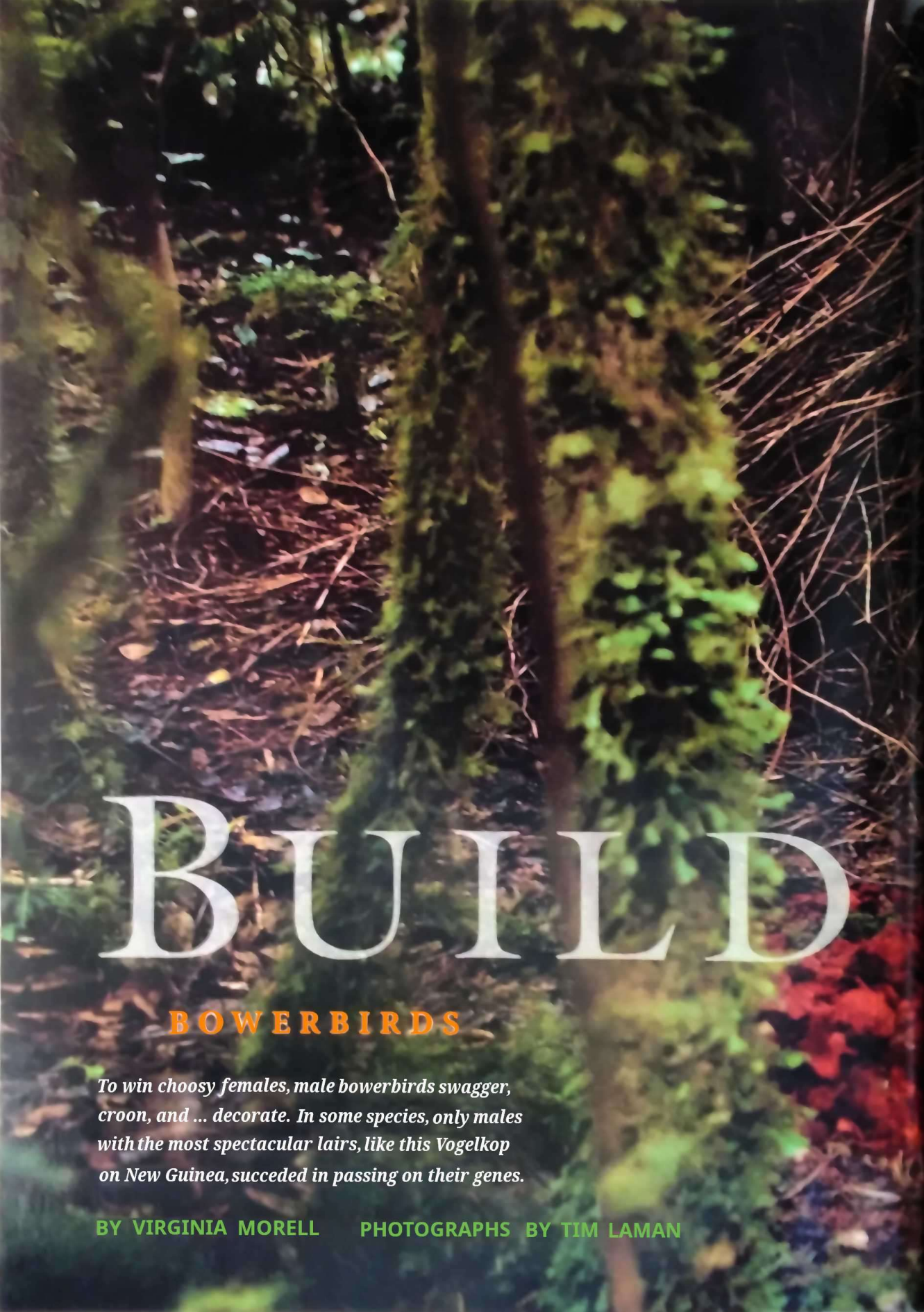
Lovejoy has a provocative answer to Jungers's question: sex. Lovejoy views the origins of bypedalism as the consequence of an epochal shift in social behavior. A key part of his theory is not something gained in our lineage but something lost, those daggerlike male canine teeth of apes, so effective as weapons against other males vying for mating opportunities. Males of virtually all living and extinct apes have large, pointed canines that sharpen by honing against their lower teeth. Hominid male canines are much smaller, more like a female's. Canines from 21 individuals were found in the *Ar. ramidus* sediments of the Middle Awash, presumably both male and female. All share the hominid pattern.

Instead of gaining access to females through conflict with other males, in Lovejoy's view a male *Ar. ramidus* would supply a targeted female and her offspring with high-fat, high-protein foods, gaining her sexual favors exclusively in return — a reproductive strategy that ensured the children he was providing for were his own. This would require, however, that the male's hands be freed from their role in quadrupedal locomotion so they could carry back the food. Bipedality may have been a pour way for *Ar. ramidus* to get around, but through its contribution to the "sex for food" contract, it would have been an excellent way to bear more offspring. And in evolution, of course, more offspring is the name of the game.

Whatever the reason for Ardi's incipient bipedality — if that's what it was — a mere 200.000 years later Lucy's genus, *Australopithecus*, appeared in the same region — fully bipedal, like all the hominids that would follow. Did primitive, splay-toed *Ar. ramidus* undergo some accelerated change in those 200.000 years and emerge as the ancestor of all later hominids? Or was it a relict species that carried its quaint mosaic of primitive and advanced trais with it into extinction?

"These finds are incredibly important, and given the state of preservation of the bones, what the discoverers did was nothing short of heroic", says Jungers. "But this is just the beginning of the story". — *Jamie Shreeve*



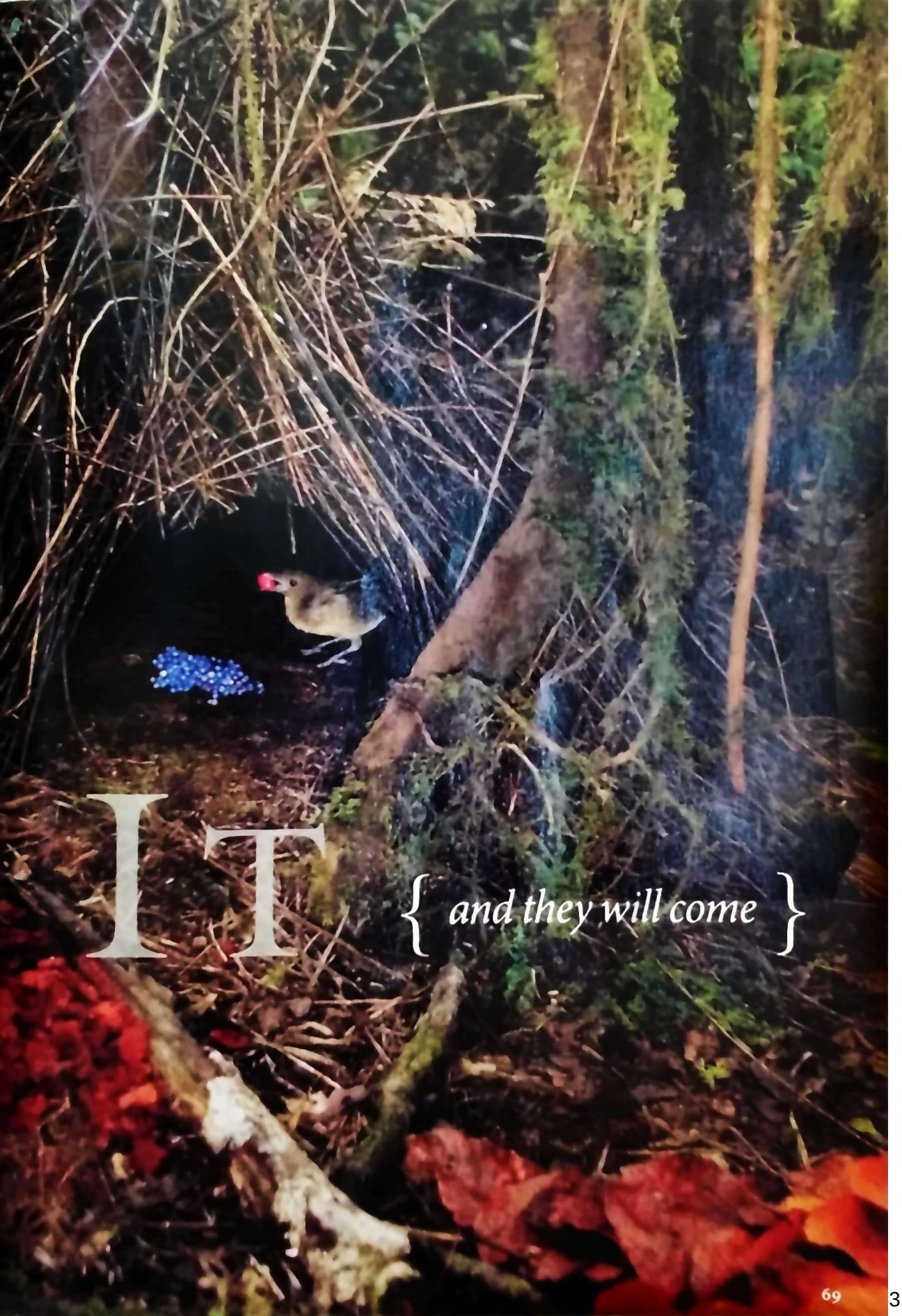


BUILD

BOWERBIRDS

To win choosy females, male bowerbirds swagger, croon, and ... decorate. In some species, only males with the most spectacular lairs, like this Vogelkop on New Guinea, succeded in passing on their genes.

BY VIRGINIA MORELL PHOTOGRAPHS BY TIM LAMAN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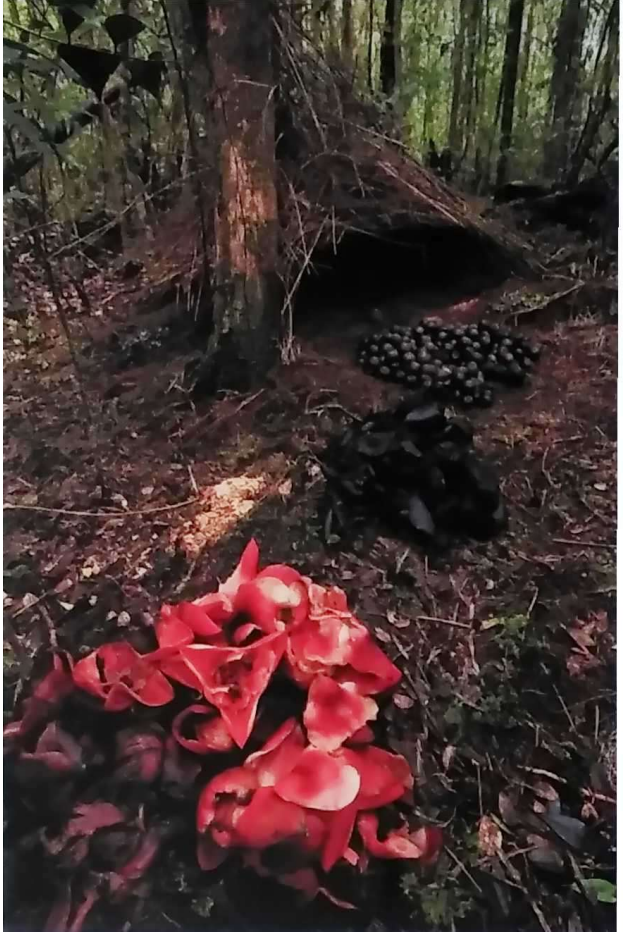
{ and they will come }



DONALD *has the tallest tower in the forest.*

It isn't as grand as the other Donald's Trump Tower, but it is impressive nevertheless, built with the one tool at his disposal: his beak. Donald, a Macgregor's bowerbird, lives in the dark woods of the Adelbert Range of Papua New Guinea. Here, atop a mossy platform and around a young sapling, he has woven his spire of sticks and twigs. At its base he has stacked piles of nuts, beetles, and cream-colored fungi; from its lower branches he has strung garlands of caterpillar feces glistening with dew. Thus ornamented, his tower soars more than three feet above the forest floor, pointing skyward like a beacon. Donald perches on a nearby tree and aims his beak in the same direction. *Rat-a-tat-tat*, he calls into the air. *Rat-a-tat-tat*.

All of this — the elaborate tower, pretty offerings, and strident calls — have one purpose: to convince female Macgregor's bowerbirds that he, Donald, and not the guy down the way, is the best male in the neighborhood, the one the gals should choose as a mate. Is Donald's fancy tower up to the task?

"That's the ultimate test", says Brett Benz, the University of Kansas ornithologist who named Donald after the real estate magnate. "OK, so he has the tallest tower around. Let's see if he can pull down a Mary". In the local pidgin, "Mary" is a term for the fairer sex.

To woo females, the males of 17 of the 20 known species of bowerbirds build structures — often resembling an arbor, or bower, with an art-fully decorated platform. Benz has measured all the Macgregor's males' bowers he's found in this forest, so he can speak with authority about Donald's achievement. Benz also knows a great deal about what Donald and other males do at their bowers, since he has video cameras set up in blinds recording the birds' every move, including their matings.

Virginia Morell is writing a book about animal minds. Biologist and photographer Tim Laman covered the Foja Mountains expedition in the June issue.

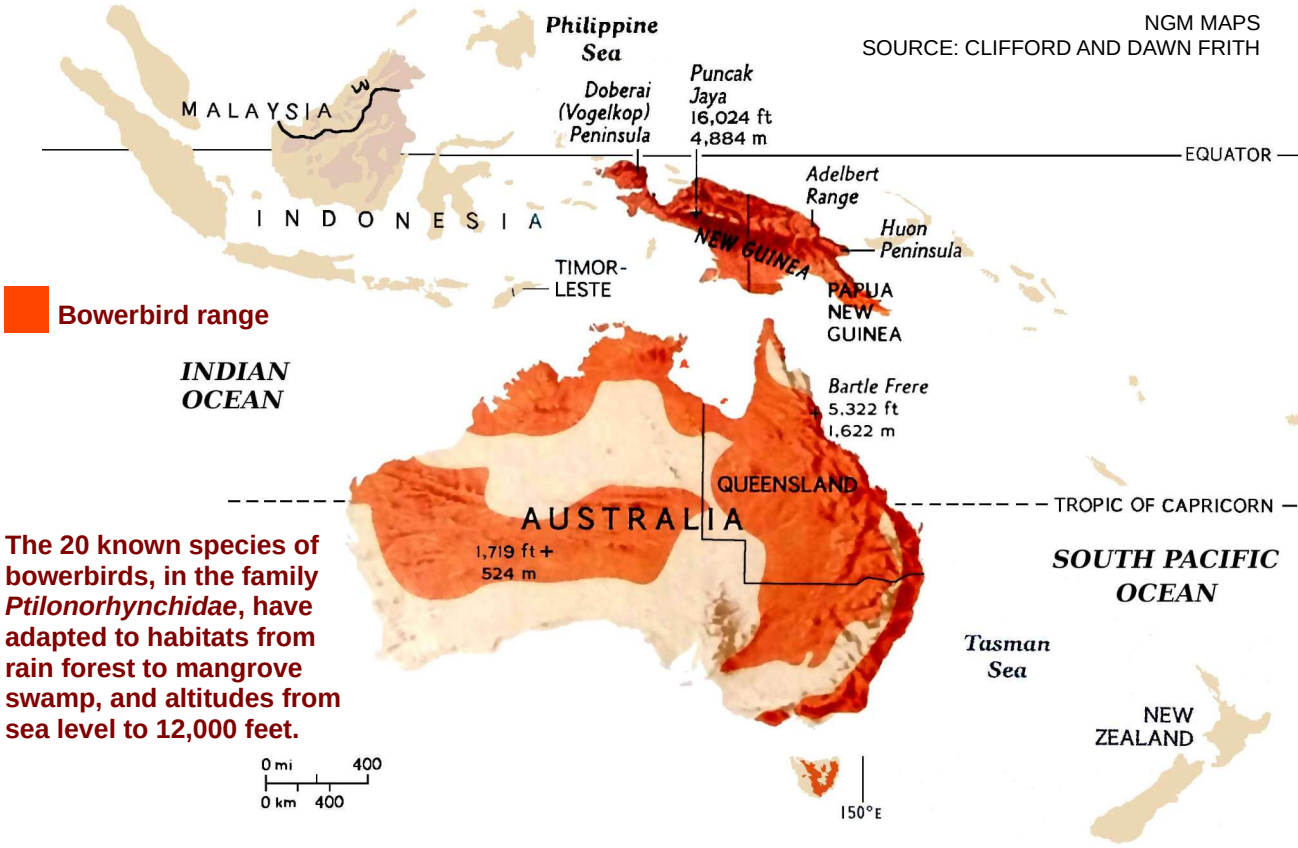
Flowers, leaves, acorns, and cans are a few of the favorite things of four rival Vogelkop males in the same vicinity. In bower decor, the Vogelkop expresses individual variation more than any other species.

AMBLYORNIS INORNATUS

Scientists are drawn to bowerbirds because they clearly show the power of sexual selection, the evolutionary force that Charles Darwin defined to explain conspicuous male traits such as song, bright colors, and horns. In most animal species, Darwin noted, females do the choosing — basing their decision on the ornamentation and ostentation males use to attract them. Because most bowerbirds are polygynous, meaning one male is the mate of more than one female, and these males build decorative bowers, they make excellent species for testing this idea. Males don't help the female build a nest, incubate the eggs, or raise the chicks — all they give her are their genes. The females are thus very choosy about which male they pick.

People also study bowerbirds because, well, because they're surprisingly similar to people. Indeed, evolutionary biologist Jared Diamond has called them “the most intriguingly human of birds”. These are birds that can build a hut that looks like a doll’s house; they can arrange flowers, leaves, and mushrooms in such an artistic manner you'd be forgiven for thinking that Matisse was about to set up his easel; some can sing simultaneously both the male and female parts of another species’ duet, and others easily imitate the raucous laugh of a kookaburra or the roar of a chain saw. Plus, they all dance. And about Donalds pile of beetles: He killed them solely for the purpose of decorating. Humans are the only other species known to use animals in this way.

Given all these talents, some researchers have attributed an aesthetic sense and the glimmerings of culture to bowerbirds, traits rarely suggested as found in any species aside from our own. (Some primates, such as chimpanzees and orangutans, are now regarded as having cultural traditions but not aesthetics.)



The 20 known species of bowerbirds, in the family *Ptilonorhynchidae*, have adapted to habitats from rain forest to mangrove swamp, and altitudes from sea level to 12,000 feet.

"THE FEMALES ARE THE JUDGES", Benz reminds me as he opens the blind. I cross my fingers for Donald and slip inside. It is just after dawn and raining lightly, the kind of weather Macgregor's bowerbirds prefer in the mating season. From the blind, I see Donald on his singing perch. He isn't much to look at: a blue jay-size fellow with plain, olive-drab feathers and a single streak of orange on his head. For a while, he makes his machine-gun-like call. Then a tatty yellow leaf falls onto his tower's mossy lawn. Donald flies down at once to remove it. The Marys would like that, I think.

All the bower builders are avid maintenance men, picky about what they collect and fussy about their arrangements. In Australia, in front of his stick-and-grass avenue, a male satin bowerbird, whose eyes are a striking blue, displays blue parrot feathers, white snail shells, and yellow and purple blossoms. For sheer obsessive collecting, few bowerbirds match the great bowerbird of the open woodlands of northern Australia. These males amass thousands of white and gray pebbles, snail shells and sheep vertebrae, piles of green and purple glass, rifle shell casings, colorful plastic strips, wire, bottle caps, tinfoil, mirrors — in short, almost anything bright and shiny, even CDs. These things please the females, of course, but the birds also use them in competing with one another. "They fight, steal each other's ornaments, and shred each other's bowers", says Natalie Doerr, a researcher from the University of California, Santa Barbara, who is documenting the items males most covet and steal from each other's bowers. "They don't have antlers to fight with, so they fight over their stuff".

Macgregor's males stage similar turf wars, but no challengers appear at Donald's tower. Back on his perch, he speeds up his song — a signal that he's spotted a female. But so have other nearby males, which also begin singing lovelorn tunes — all of them vying for this one lady in the treetops. The rain pours down harder, Donald's call intensifies, and like any chick-lit fan, I just want to know: Whom will this Mary choose? I keep my fingers crossed for Donald.

Master engineers, Macgregor's bowerbirds in New Guinea may spend weeks erecting, and years perfecting, a "maypole" bower up to seven feet high atop a ring of moss (above). A subspecies on the Huon Peninsula (left) adds white flowers to the base of its maypole for contrast and extra flair.

AMBLYORNIS MACGREGORIAE

Donald runs through an impressive repertoire of bird and tree frog trills, then hops down to his mossy mat. He hunches behind his tower and points his beak at the treetops while softly peeping. Suddenly, on the opposite side of his tower, another Macgregor's bowerbird appears — colored like Donald, but with a slightly rounder head. A Mary!

OK, Donald can pull down a Mary. Now he needs to make her stay.

Donald and the female begin a game of hide-and-seek. He unfurls his previously hidden carrot-orange crest and streaks out at her, wings askew, then darts back to hide again. His crest is spiky, bright as a hot chili, making him look a little like Rod Stewart. Clutching at the moss, he bobs and sways and chirps and sings like a rock star. Then he races behind his tower and jumps at her from the other side. Back and forth, around and around the tower the two run, Donald dashing toward her, as the object of his desire runs to the other side to try to get a better look at him and his flaming crest.

If the female chooses Donald, they will mate on the mossy platform, but alter ten minutes she steps to the edge of the moss and flies away. She apparently doesn't give Donald the signal to follow, because he stays at his tower and calls and calls again, his pitch rising ever higher.

What has he done wrong?

"Maybe nothing", Benz says, when I return to camp. "I'd guess that wasn't her first visit at Donald's. And I'd bet she'll be back".

Perhaps Donald thinks so too. Or perhaps he hopes another Mary will come. Either way, he doesn't dither but gets to work again. He tucks his party crest away and putters around the base of his tower, carrying off bits of broken moss and twigs. He rearranges the nuts and straightens up his beetle pile. As a last touch, he adjusts the garlands of caterpillar feces. He steps back and eyes the whole structure, deciding, it seems, that the tower is ready for another visitation. Then Donald jumps back on his perch and starts the song again. *Rat-a-tat-tat*, he calls. *Rat-a-tat-tat*.

The gunk on the satin bowerbird's beek is plant matter, which he mashed up to paint his bower's inner sanctum in a rain forest in Queensland, Australia. The pulp adds a hint of colour and perhaps flavour: Females sometimes take a taste during the male's display.

PTILONORHINCHUS VIOLACEUS MINOR

NA

Flaunting an insect in his beak, a satin bowerbird makes noise, flaps his wings, and dances for the female sizing him up in the avenue of his bower. If the wooing works, he'll swoop to the rear and mate with her—a male's sole contribution to family.

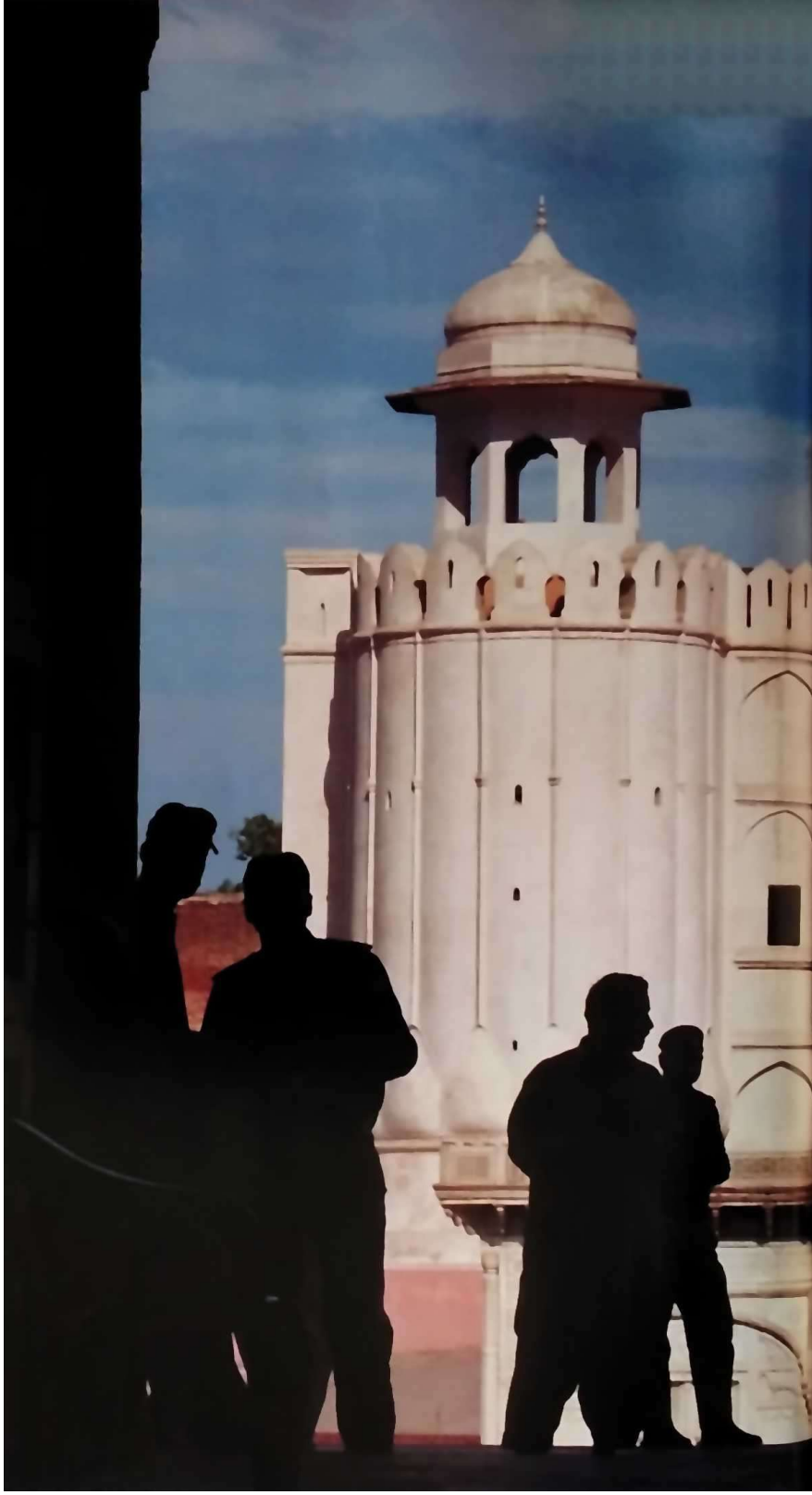
PTILORHINCHUS VIOLACEUS MINOR

What turns on female great bowerbirds in a Queensland park? Big piles of stuff, some man made bits like plastic toys, and a gray-green palette. A male's welcome mat may display thousands of items — found, filched, or inherited from a previous occupant.

CHLAMYDERA NUCHALIS

Not every bower is a palace. A leaf-strewn court (top left), meticulously created by a tooth-billed bowerbird in Australia, may represent an ancestral type from which the more elaborate maypole and avenue styles evolved. Like all bowers, a great bowerbird's twiggy avenue (bottom left) is used only for courtship and not as a nest. The outer pile of stones is the stage for his theatrics once an admirer is lured within. But not even the prettiest pink offering guarantees the prize. Though males seem to do all the right things, females sometimes simply fly away.

CHLAMYDERA NUCHALIS



Heightened security during Friday prayers means armed guards stand watch at Lahore's Badshahi Mosque. Completed in 1674, it can welcome 100,000 worshippers.

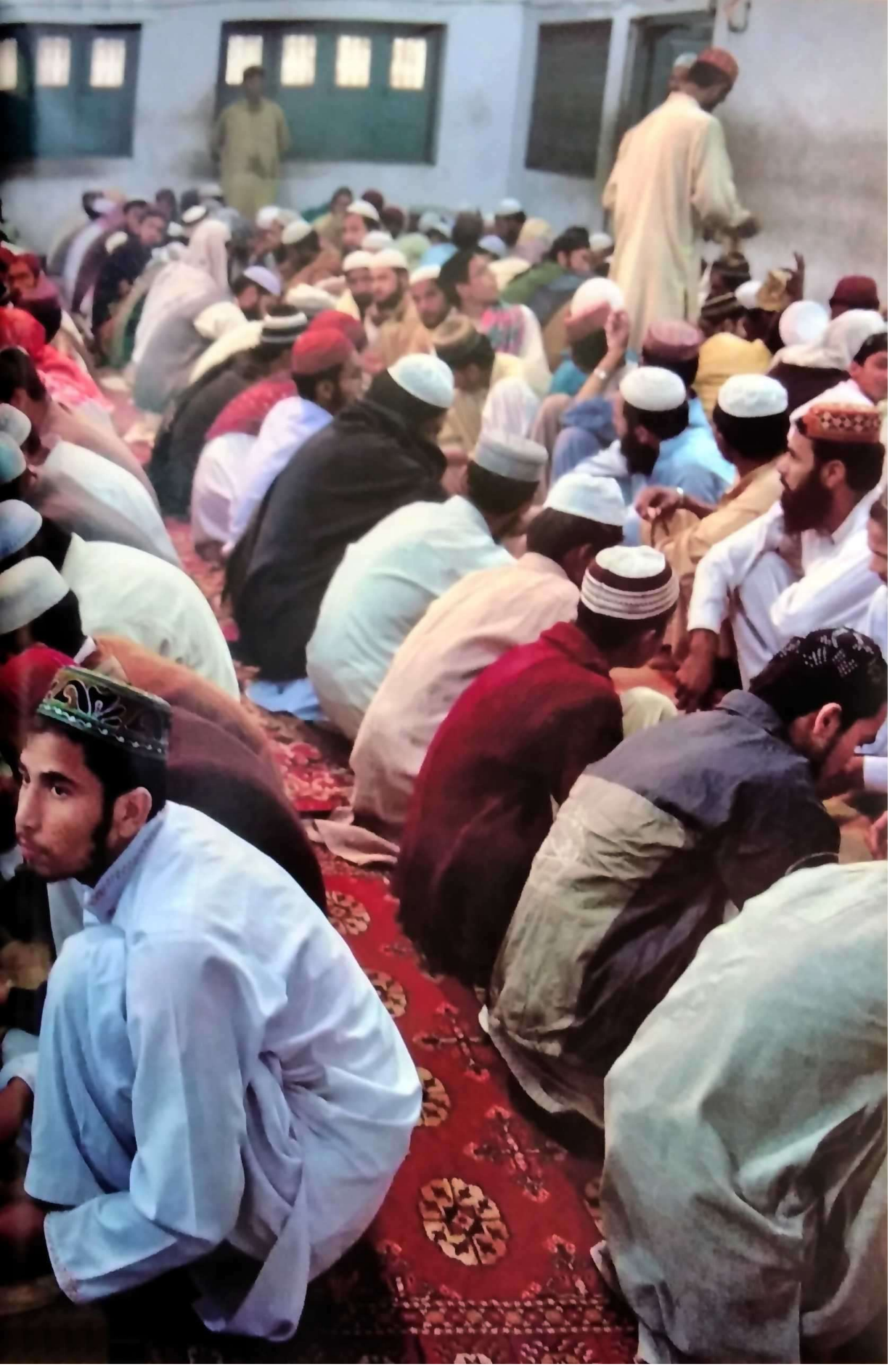
Pakistan's Heartland

WEST MEETS EAST IN PROSPEROUS, POPULOUS PUNJAB,

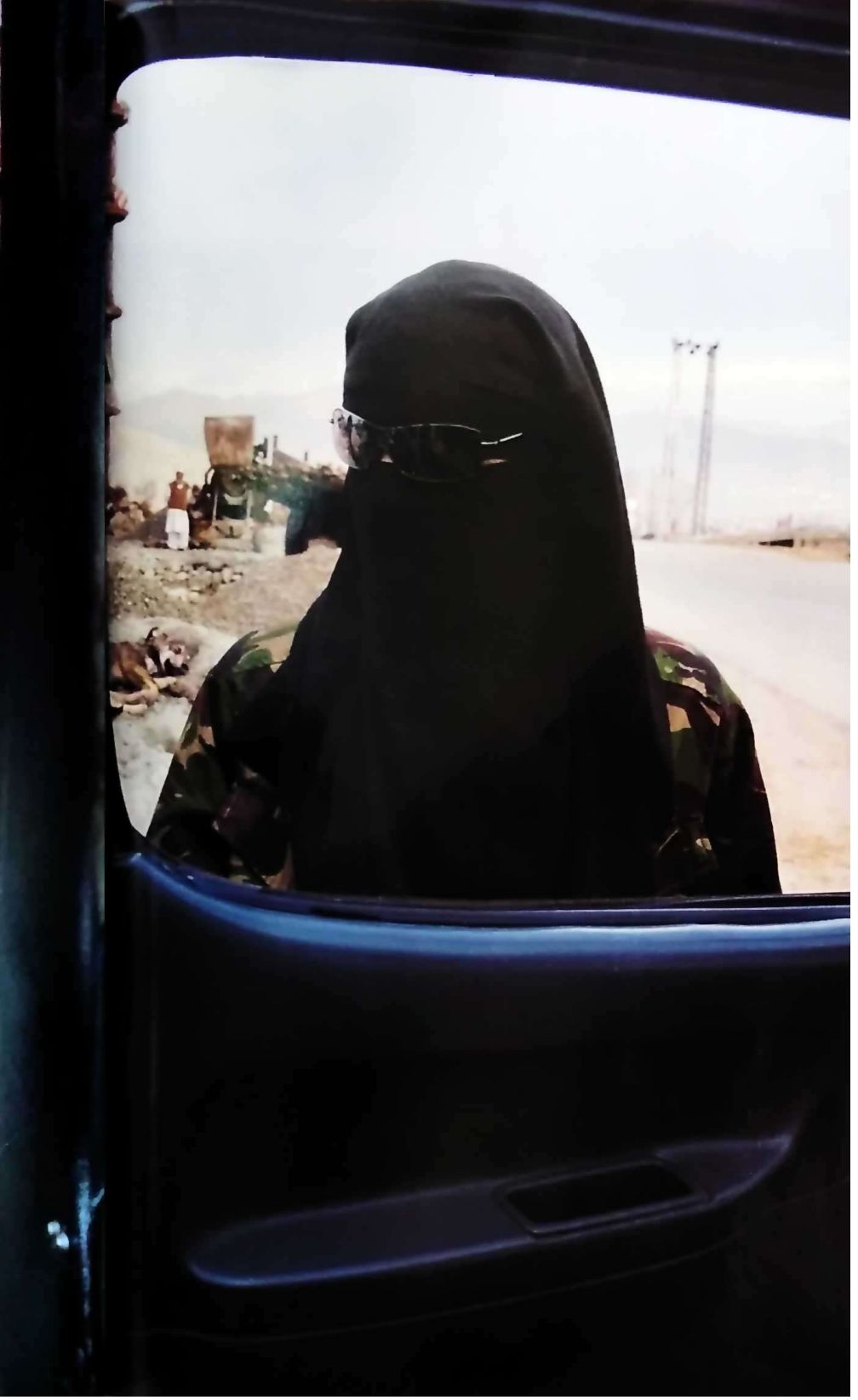
Under Threat

BUT THE TALIBAN WANTS TO CHANGE THE STATUS QUO.

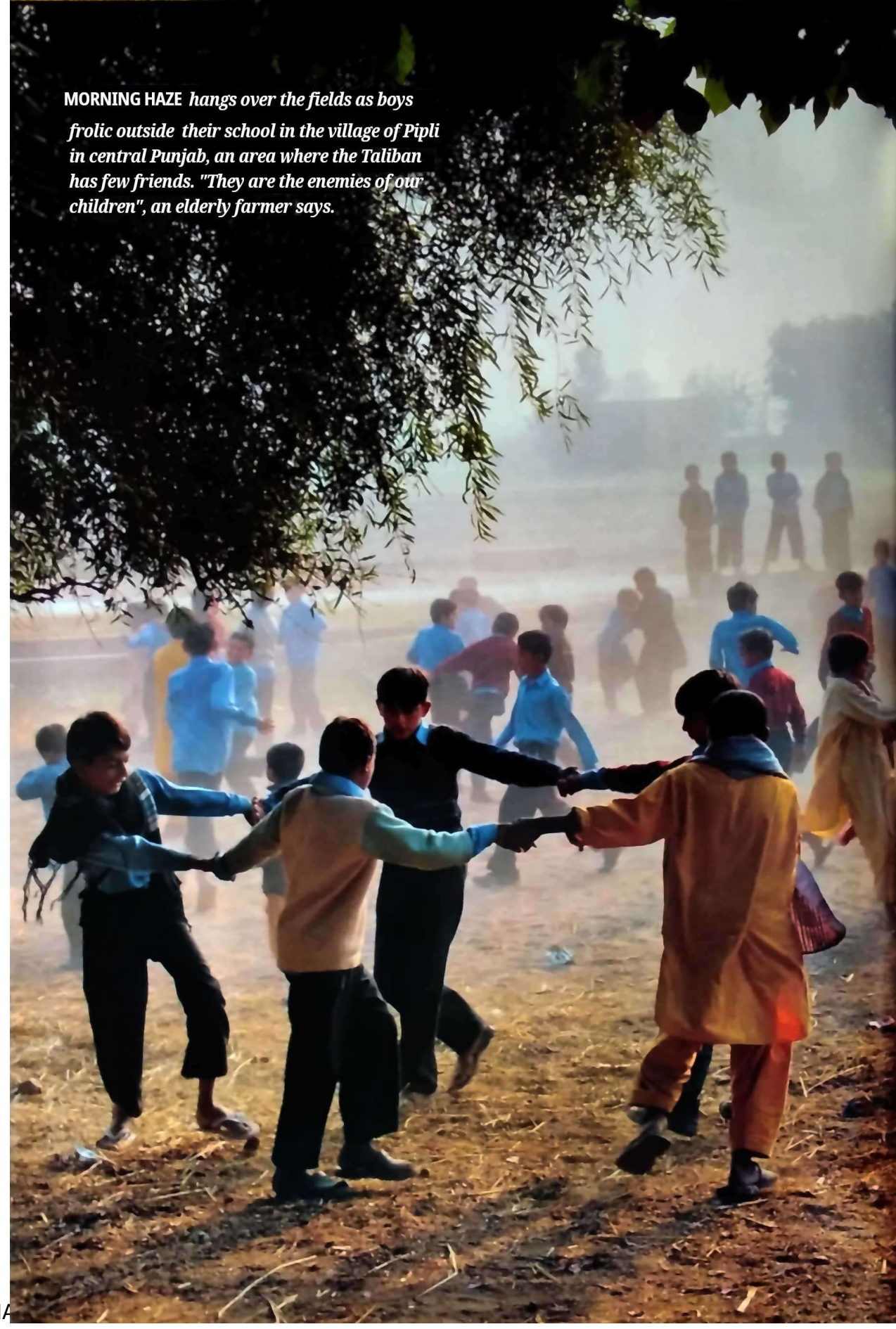
FREE MEALS *and lodging are provided by this madrassa in Gujranwala in northeastern Punjab. As in many such schools, the leaders are sympathetic to the Taliban and have resisted government pressure to modernize.*



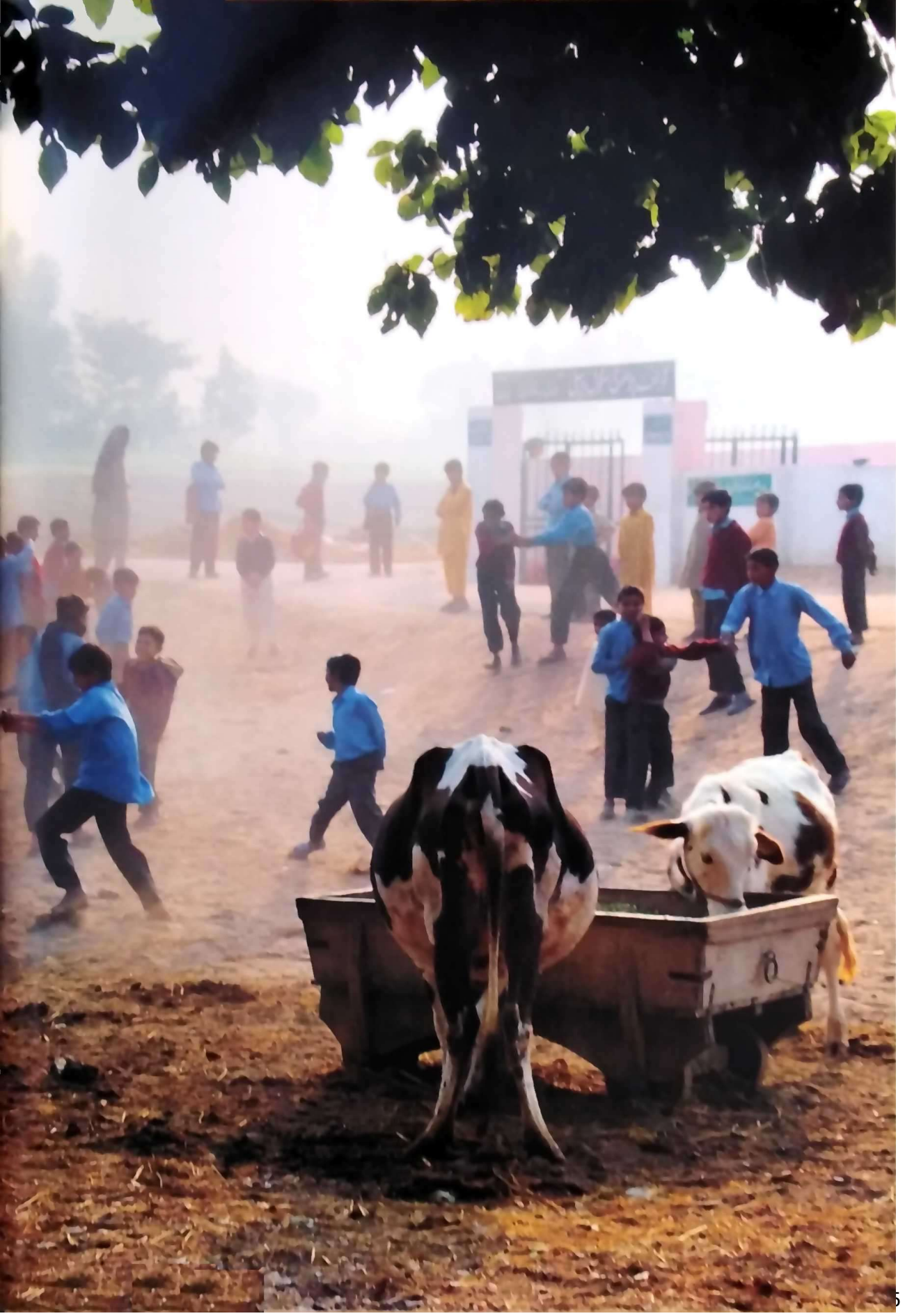
IDOL WORSHIP *is what extremists call it. But Sufis call it love. Here is the town of Mithankot, women share a mystical moment at the shrine of Khwaja Ghulam Farid, a revered 19th-century poet they consider a saint.*

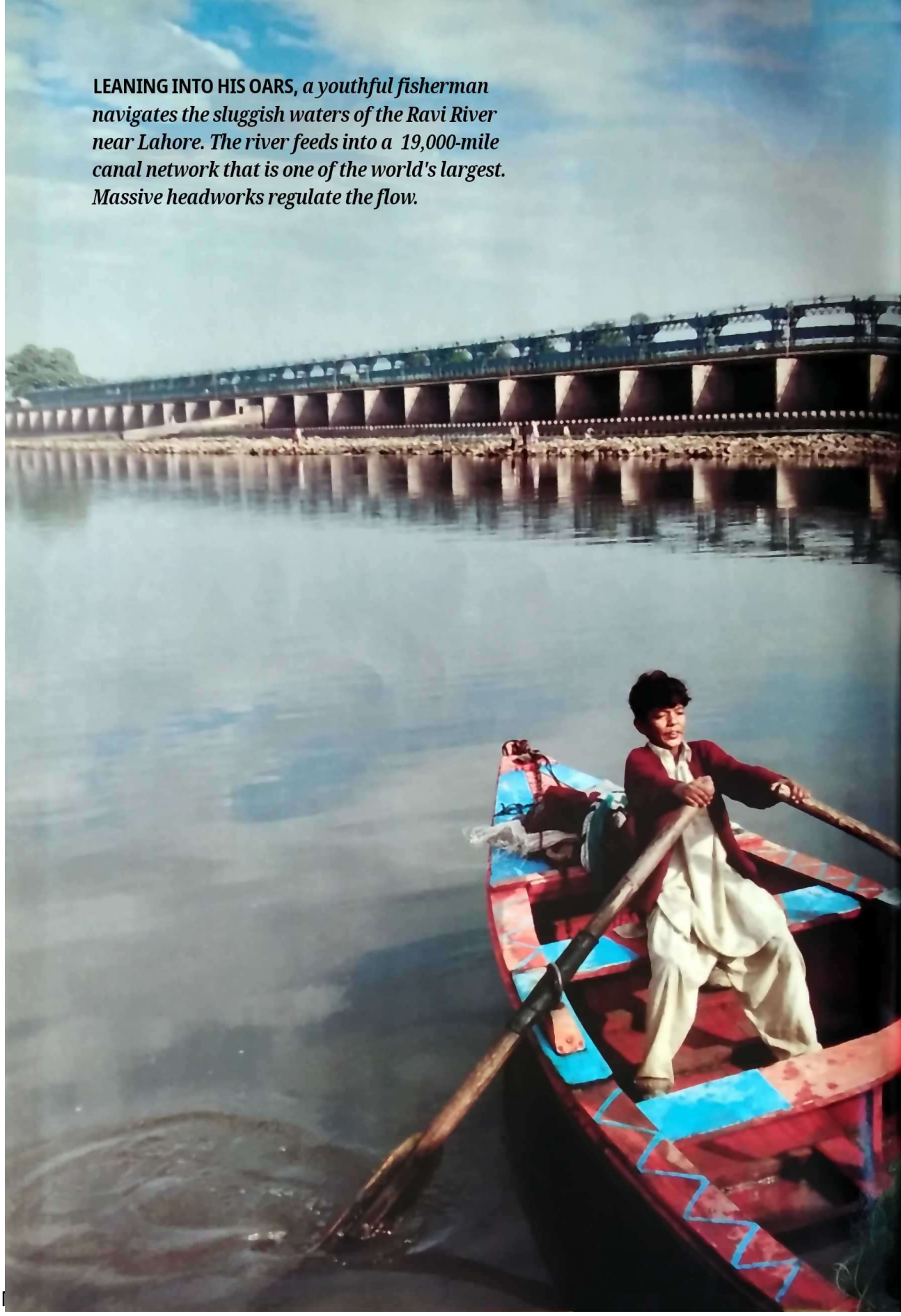


A MASKED INTERPRETER shares checkpoint duty in a Pashtu-speaking region where the Punjabi-dominated army is not always welcome. The interpreter, a local man, fears Taliban retribution if he is seen helping the troops.

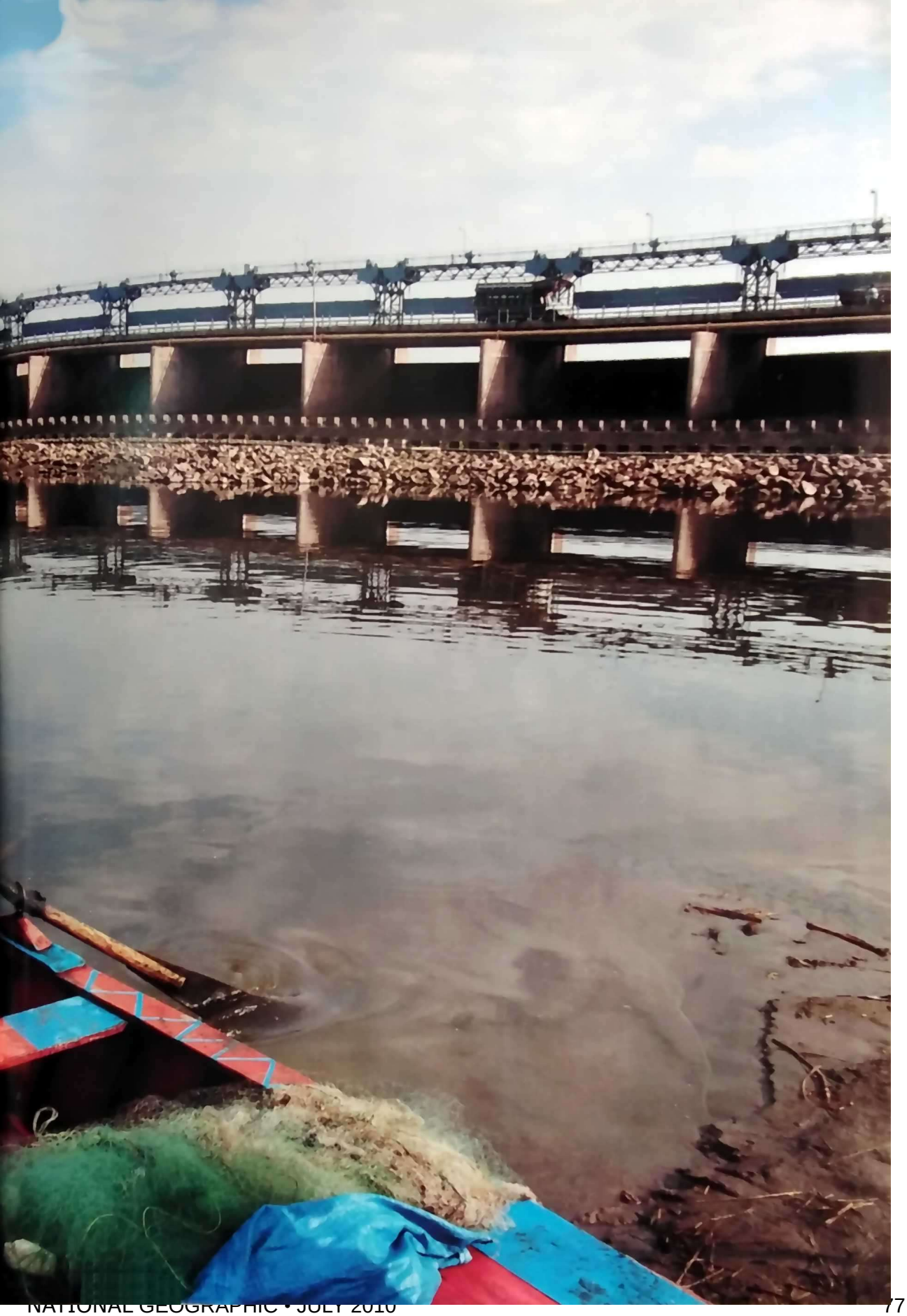


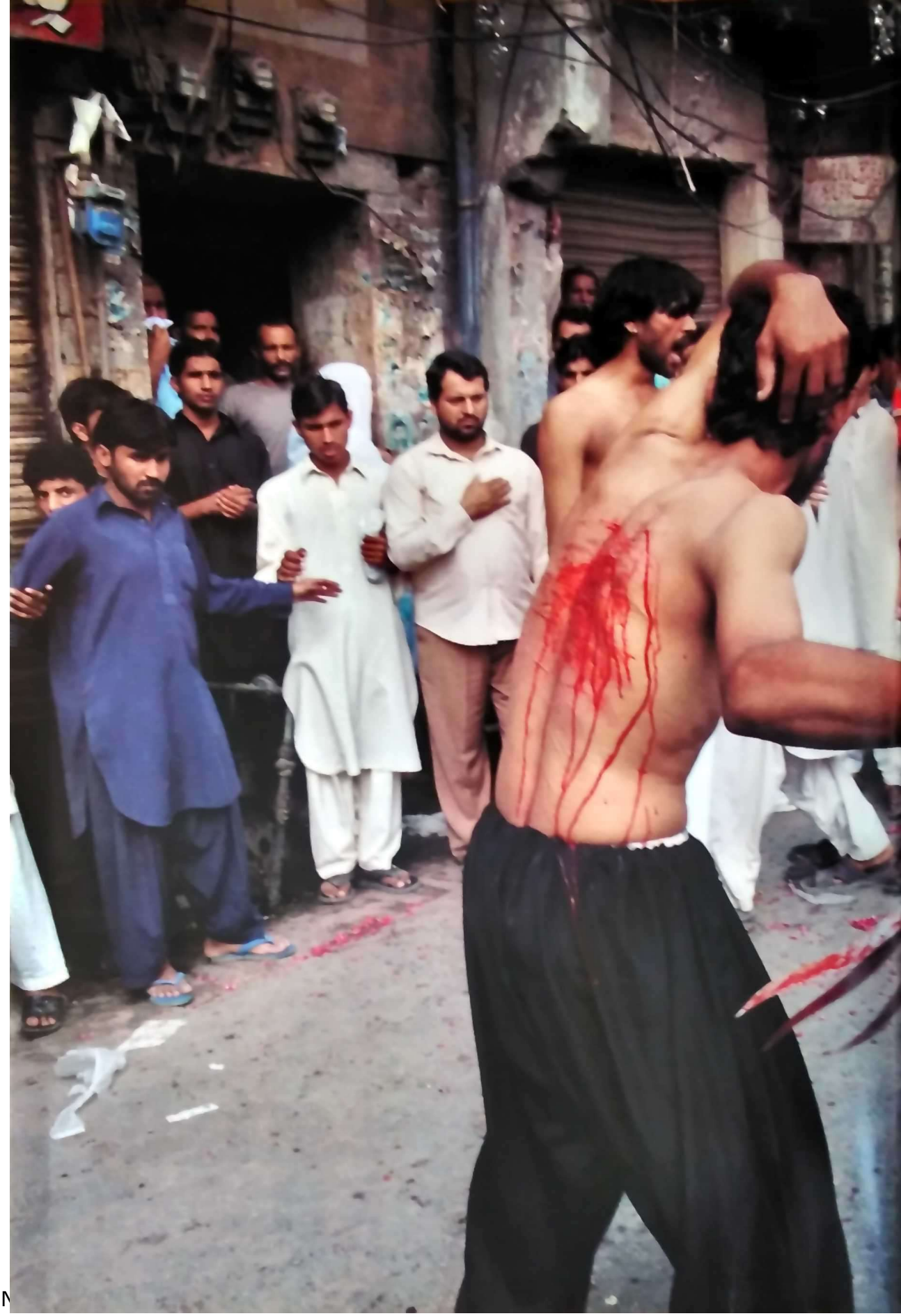
MORNING HAZE *hangs over the fields as boys frolic outside their school in the village of Pipli in central Punjab, an area where the Taliban has few friends. "They are the enemies of our children", an elderly farmer says.*





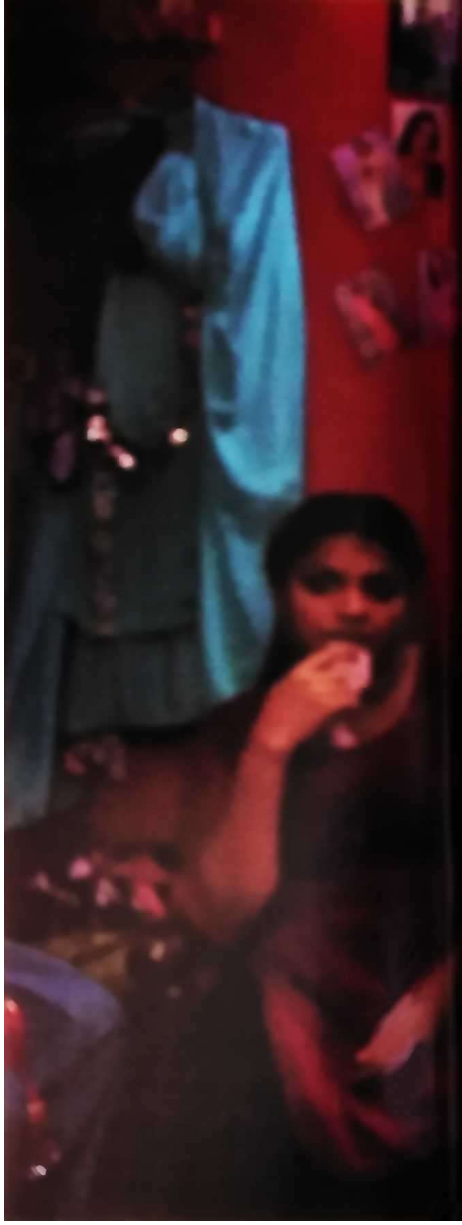
LEANING INTO HIS OARS, *a youthful fisherman navigates the sluggish waters of the Ravi River near Lahore. The river feeds into a 19,000-mile canal network that is one of the world's largest. Massive headworks regulate the flow.*





HIS BACK BLOODIED, *a Shiite man in Lahore whips himself with blades in a ritual that symbolizes the suffering of Muhammad's grandson Husayn—and the Shiites' collective guilt at not having come to his aid.*

By JOHN LANCASTER
Photographs by Ed KASHI



The Taliban would not be amused. On a sunny winter afternoon in Lahore, the local culturati have turned out in force for the annual show at the National College of Arts. In the main courtyard young men and women mingle easily, smoking and sipping from cans of Red Bull. Some of the men sport ponytails, and one has a pierced eyebrow.

Nearby is a life-size sculpture ofa couple holding hands on a swing. Inside, the image of a male torso, viewed from one angle, morphs into a female breast. Yet there is no mistaking the stamp of the subcontinent. Women wear traditional thigh-length tunics over their jeans, and some cover their hair. There are also miniature paintings, which traditionally might capture a hunting scene; here they portray other scenes, as in one bold depiction of a bearded cleric reclining on a couch in front of a bombed-out school.

The jumble of styles and influences — the stew of peoples and faiths Rudyard Kipling captured so vividly in his novel Kim — is a hallmark of Lahore, Pakistan's second largest city and capital of Punjab Province. The wealthiest and most populous of the country's four provinces, Punjab is where East meets West and everything in between. Even the brutal and bloody partition of British India in the mid-20th century could not destroy Punjab's cosmopolitan brio.

But the Taliban and its allies are doing their best. In the past few years they have unleashed a wave of terrorist mayhem in Punjab, the home turf of Pakistan's political and military establishments, that has targeted even the visiting Sri Lankan national cricket team. The intrusion of violence from the remote tribal badlands near Afghanistan has shocked Punjabis, who until recently tended to dismiss the extremists as someone else's problem. It also has raised fears in Washington that nuclear-armed Pakistan, an inconstant but vital partner in the war on terrorism, could be heading toward collapse.

The Punjab I knew in the years after 9/11, when I covered Pakistan as a foreign correspondent, was relatively undisturbed. To be sure, it suffered from a myriad of social ills and had its share of homegrown Islamist militants. But the guardians of the status quo — generals, feudal landlords, industrialists — remained deeply entrenched, as did Sufism, the tolerant, mystical, music-and-poetry-saturated brand of Islam that is anathema to many Muslim hard-liners. Could the fabric of society here really come unraveled?

A few days after the art show I tracked down Imran Qureshi, head of the college's miniatures department, at the modern, two-story home he shares with his wife and two young children. A boyish 38-year-old in corduroys and a zippered sweater, he showed me into a living room decorated with tribal rugs and Scandinavian-style wood furniture. Qureshi and his wife, Aisha Khalid, both renowned artists, could easily migrate to London or New York, where they often show their work. But they have no intention of leaving. "I think it's getting more liberal here", Qureshi said, his voice swelling with enthusiasm. "People are talking about politics, sexuality, all kinds of issues. It was not like this ten years ago".

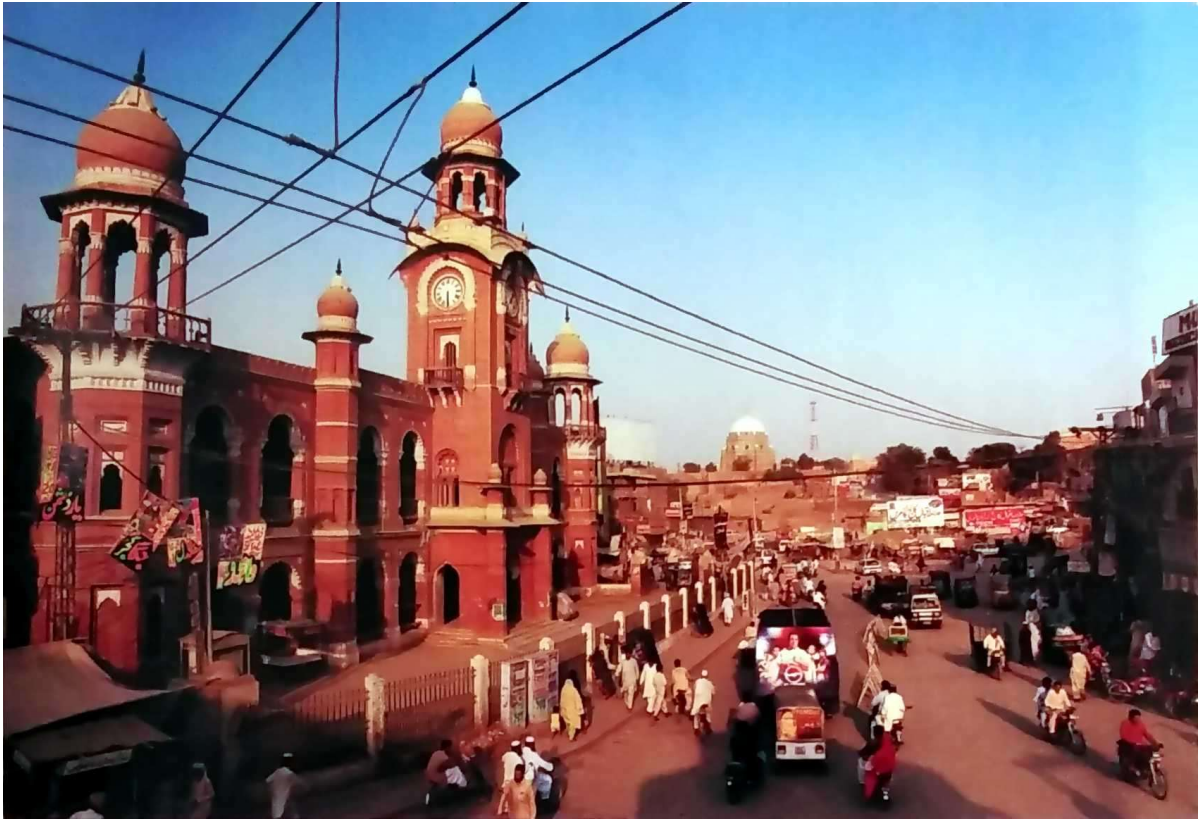
BOLD LIPSTICK *and bawdy dancing are the trademarks of Nida Chaudhry, who performs to packed houses at Lahore's Al Falah theater. "Whatever we do is the demand of the public", she says. "We ourselves are all Muslims".*

"I think it's getting more liberal here", Imran Qureshi said. "People are talking about politics, sexuality, all kinds of issues. It was not like this ten years ago."

Qureshi's commitment to his country and his art was impressive, and so was his apparently sturdy faith in Punjab's civility and resilience. On the other hand, perhaps he was simply in denial.

John Lancaster was South Asia bureau chief for the Washington Post.

Ed Kashi's coverage of Syria was published in the November 2009 issue.



RELICS OF THE BRITISH EMPIRE *include this clock tower in the southern city of Multan, accented with cupolas and keyhole arches borrowed from native styles. Multan is also known for its many Sufi shrines, like the 14th-century, white-domed tomb in the background.*

IF GEOGRAPHY IS DESTINY, there are few better examples than Punjab. Wedged between Central Asia and the subcontinent, the region was squarely in the path of invaders — Macedonians, Turks, Mongols, Persians, Afghans — as well as trade caravans traveling between the subcontinent and points west. Lahore became the capital of a succession of imperial dynasties, and a focal point of surprising diversity. In the late 16th century, the Mogul emperor Akbar infuriated orthodox Muslims by flirting with Hinduism and Christianity. The Sikhs who later ran the city and its environs paid for the upkeep of mosques and Hindu temples, along with their own gurdwaras. The British added universities and stone churches, and Punjabis learned to love cricket and the queen's English, if not the queen herself.

All was torn asunder by the partition of the subcontinent into India and Pakistan in 1947. Punjab was the richest and most bitterly contested prize, and the largest share, an area the size of Wyoming, was awarded to Pakistan amid a spasm of communal bloodletting that killed up to a million people. Five million Hindus and Sikhs fled to India, and eight million Muslims streamed the other way.

Punjab now accounts for almost 60 percent of Pakistan's economy and is slightly more populous than Germany, with about 90 million of Pakistan's 173 million people. In terms of income it is roughly on a par with Sindh, which includes the sprawling financial and industrial capital of Karachi.

The national capital was shifted from Karachi to newly built Islamabad, near the army headquarters in Rawalpindi, in 1967. But Lahore, a frenetic and timeworn city of eight million, is arguably Pakistan's cultural capital and a living expression of the history of its people.

LIKE THE STUDENTS at the arts college, the young men who attend Aitchison College, an exclusive boys' school founded by the British in 1886, reflect many of the contradictions of modern Pakistan. The boys wear blazers stitched with the Aitchison crest ("Perseverance Commands Success") and every day at sunset stand at attention in front of their dorms as the school flag is lowered to a bugler's squeaky rendition of the "Last Post".

The Sikhs once ran the city. The British added universities and stone churches. The Punjabis learned to love the queen's English, if not the queen herself.

The Aitchisonians, thoroughly versed in American pop culture, chatter at dinner about the relative hotness of J-Lo and Salma Hayek. At the same time, the boys have been shaped by the Islamization of Pakistani society that began in the late 1970s during the military dictatorship of General Muhammad Zia-ul-Haq. Both they and their teachers are infused with a strong sense of Muslim identity and, at times, grievance, especially toward the United States. "We all thought you were a spy", one of the teachers told me after I spent time teaching at the school in 2009. "We hate Americans".

Lahoris of an earlier generation pine for the more permissive and worldly era that preceded Zia's rule. Yet Lahore's cultural life lives on. One of the more popular lowbrow diversions is a theater that features live performances by comedians and dancers. The grimy auditorium is always packed with men, some obviously drunk. As burly guards with Kalashnikovs keep order, dancers in satin leotards and filmy tunics shimmy across the stage to the screech of recorded Indian film songs.

A QUIET INTERLUDE *between prayers is the best time to savor the majesty of the Badshahi Mosque. Its marble domes and graceful minarets rise above Lahore's Old City, evoking the glories of Punjab's imperial past.*

DANCING HORSES *are trained by Faizal Abbas (left), a feudal landlord who pursues the hobby at his compound near Multan. But life is hard for many Punjabis. On a police-man's land in Goraya, villagers thresh rice in exchange for a share of the crop.*

The dance routines are interspersed with skits full of bawdy humor and double entendres. Men howl vulgarities and at the end of the night shower their favorite dancers with crumpled rupee notes.

One of the dancers is Nida Chaudhry. Waiting backstage between numbers one night, she wears magenta lipstick and purple eye shadow that make her look older than her 20-some years. A recent citation for risqué dancing does not seem to have cramped her style. "What should I do?" she asks. "Should I dance in a burka?"

Punjab was the richest and most bitterly contested prize, and the largest share was awarded to Pakistan amid a spasm of communal bloodletting.

The wildest dancing I saw in Lahore was not in a theater but in a place of worship. Late on a Thursday night hundreds of mostly young men gathered at the tomb of a 17th-century Sufi spiritual leader, or saint, named Shah Jamal. They formed a tight circle around a trio of drummers and a pair of long-haired dervishes, who whirled at dizzying speeds on a tiled courtyard slick from rain showers and crushed rose petals. Hashish smoke drifted over the crowd, along with chants of "Allah! Allah-u!" and the names of various saints. The dervishes collided, and a shoving match erupted. "It's our version of rave", a Punjabi friend later explained.

Actually there's a bit more to it than that. Sufism has flourished in the subcontinent since its arrival centuries ago in the wake of Turkish armies. It centers on the veneration of saints, often with help from qawwals — singers of devotional songs whose mesmeric rhythms are said to induce spiritual ecstasy. Famous saints such as the 18th-century poet Bulleh Shah were once persecuted for their liberal and iconoclastic views. Today their graves are pilgrimage sites for millions of steadfast followers.

THE SPECTACLE AT SHAH JAMAL'S tomb was but one expression of Sufism. Last September I drove with photographer Ed Kashi to Mithankot, a town in Punjab's far southwest. It is the burial place of a l9th-century saint named Khwaja Ghulam Farid and close to a district where the Taliban is said to have made inroads. But the Sufis in Mithankot seem not the least bit intimidated. The night we arrived, a few thousand men, women, and children had assembled for a festival at the saint's domed burial chamber, which was draped with green lights. The crowd chanted "O Farid, the truth!" and listened, enraptured, to the saints poetry of divine and romantic love, sung by a harmonium-playing qawwal. A white-bearded man gripped my arm. "We like Jesus!" he declared in English. "Jesus is a prophet too!"

The town of Pakpattan is the burial place of Baha Farid — a beloved 13th-century Sufi mystic who is remembered for, among other things, his sweet tooth. On a Sunday afternoon pilgrims were tossing candy onto the shrine's marble plaza, which was sticky with the evidence of their love. Men filed into the burial chamber to kiss the green cloth that covered the saint's sarcophagus.

Sitting just outside was Ashran Bibi and her 25-year-old daughter. (As at most such shrines, women are barred from the tomb itself.) Bibi, a laborer's wife, explained that her daughter had suffered from breathing problems since eating pesticide in a suicide attempt. They had traveled to the shrine three days earlier in hopes that Baba Farid could accomplish what doctors so far had not. "He has good access", Bibi said, waving her arm at the sky. "We bring our problems to him, and then he takes our problems to Allah".

THE GUARD AT A MADRASSA in the southern city of Bahawalpur, on the edge of Punjab's desert region, was not as friendly. As soon as we emerged from our vehicle, he brandished a pistol and made it clear that photographs were unwelcome. His reaction was no surprise. Madrassa Taleem ul-Quran is an Islamic seminary affiliated with Jaish-e-Mohammed, an extremist group that has been linked to al Qaeda. The group and others like it in Punjab once operated with the support of the government, which used them as proxies in its struggle with India over Kashmir. After 9/11 the government banned the groups under U.S. pressure, but failed to prosecute their leaders or regulate the madrassas that feed their ideology. Pakistan has thousands of madrassas, many of which draw their ideological inspiration, and sometimes financial support, from Saudi Arabia.

A ROCKY STREAM *is no barrier in this remote tribal region of southwestern Punjab, where the people are as rugged as the land. Culturally more in tune with nearby Balochistan, they speak their own dialect and do not consider themselves Punjabi.*

The Jaish madrassa fronts a quiet street. Because it was the holy month of Ramadan, the seminary was not in session when we arrived, but construction work on a new fourth floor suggested that it suffered no lack of resources. A street-level store sold alcohol-free perfume along with books glorifying insurgent martyrs in Iraq and Afghanistan.

I didn't expect to get past the gate, so I was surprised when, after a phone call or two, we were invited to return later that day to meet the *nazim*, or chief administrator. “It is in the tradition of the Prophet to be hospitable”, said Maulana Imdad Ullah, greeting us in a small anteroom over tea and lemon biscuits.

A self-assured man with an unexpectedly warm smile, the *nazim* asserted that the madrassa was purely a religious institution. But he made no secret of his sympathy for Jaish or its leader, Massood Azhar, whose father founded and runs the school. “It should be a natural desire for every Muslim to follow in his footsteps”, he said. I asked if students were encouraged to take up arms against U.S.-led forces in Afghanistan. “When they graduate, it's their own choice if they want to go to jihad or not”, he said. And what exactly did he mean by “jihad”, which can be defined in many ways? “Jihad is fighting and killing”.

The nazim’s candor was striking, as was the government’s apparent willingness to let him operate unhindered. So the following morning I paid a visit to Mushtaq Sukhera, the senior police officer for the region, at his official residence. He turned out to be a charming, well-educated man with a practice green on his front lawn and a son at New York University. Sukhera was no fan of extremists and said that his men kept a close eye on the madrassa we had visited. But, he added, “they are teaching the normal syllabus that is being taught in any madrassa, so what does one do about that?”

DANGEROUS AS THEY ARE, Punjab’s militants only recently arrived in the province. For a glimpse at a more established pillar of society, we traveled to Multan, the largest city in southern Punjab and a stomping ground of the wealthy, landed aristocrats known as feudals. Faizal

TEN-GALLON HATS, *waiters who slam drinks on tables, and Beyoncé videos set the tone at Gunsmoke, a cowboy-themed steak house that is one of the more conspicuous examples of Western influence in Lahore. Religious conservatism hasn't dimmed its popularity.*

Abbas, 39, with close-cropped, gray hair and the hint of a double chin, greeted us outside his air-conditioned reception hall in a walled garden stocked with peacocks and miniature ponies. A huge lion paced in a cage.

Anything less would have been a disappointment. The feudals acquired their land in colonial times or even earlier, and many have parlayed their riches into political careers. As the city grew up around them, Abbas and his brothers sold off some of their land for development and now earn part of their living from a gas station. Lunch arrived in a box from Pizza Hut.

The family still owns several thousand acres of prime farmland — much of it planted in mangoes — and revels in its feudal roots. Behind Abbas's garden is a reproduction of his ancestral village, with an outdoor clay oven and rope cots of the sort he slept on as a child. After lunch he showed off one of his prized dancing horses.

Abbas's younger brother, Ghulam, was planning a run for public office. In the garden that night he presided over an informal council gathered to resolve a land dispute between a man and his nephew that had escalated into a display of firearms. After much back-and-forth, the pair agreed to suspend hostilities until Ghulam had a chance to see the disputed property for himself. "We are well-known", he explained later. "The bane of this public life is that I do not have a private moment".

The feudals are not universally beloved in Punjab. Halfhearted land reforms have failed to eradicate pockets of deep poverty, especially in the water-starved south. Poverty, in turn, is often blamed for fueling extremism by encouraging landless parents to send their children to madrassas, where at least they'll be fed and sheltered.

LEAVING THE UNKEMPT STREETS of Multan, I drove north through lush fields of sugarcane and rice, past textile mills and service plazas with mini-marts and prayer rooms. Near Islamabad

I came upon a vast, unfinished housing development dotted with water towers. Curving boulevards were flanked by Mediterranean-style villas that could have been transplanted from southern California or Abu Dhabi. A billboard advertised a new swim and tennis club.

The development belongs to Pakistan's biggest real estate developer and most powerful institution — the army. Officers buy land at below-market prices, then build on it or sell it to private buyers for a profit. The perk is a result of a sprawling network of army-run welfare schemes and businesses, including cement factories, fertilizer plants, and Pakistan's largest trucking firm. Nowhere is the system more deeply rooted than in Punjab, where the British Indian Army focused its recruiting and its Pakistani successor still does.

Hashim Khan is one of the systems beneficiaries. A retired brigadier, he works for a military contractor and lives in the army-run development. He met me near the entrance in his black Lexus SUV and drove me to his 10,000-square-foot home, where a gilt-framed portrait of his army officer father hung in the marble foyer. A hearty sort with a mustache and straight brown hair, Khan showed me into the study he called his I Love Me Room, which was equipped with a humidor and a refrigerator stocked with Heineken. Pavarotti played in the background.

Army personnel, however, have no monopoly on upscale neighborhoods. In the northeastern city of Sialkot, the roads are flanked by sidewalks, sewers are covered, and digital displays count down the seconds at traffic lights. As it happens, Sialkot is one of the world's top manufacturing centers for surgical instruments as well as sports equipment — especially hand-stitched soccer balls sold under brands such as Nike and Adidas — and some of the exporters contribute to public amenities of the sort they often see on business trips abroad. Khawar Anwar Khawaja, a Sialkot native whose company makes cricket balls and bats in partnership with a British firm, says "There was always this simmering anger that we were so far behind". Exporters had for years lamented the need to truck their goods to airports in Islamabad or Lahore. So Khawaja persuaded fellow movers and shakers to buy shares in a new private airport — the only one of its kind in Pakistan — to serve cargo and passenger flights from the Middle East and Europe. It opened in late 2007.

Khawaja is under no illusions, though. He is as frustrated as anyone by daily power failures, the dismal state of Sialkot's public schools and hospitals — to say nothing of the Taliban. But he enjoys a good life in the city, where he lives with his wife in an ivy-covered villa and plays golf and tennis at nearby military clubs. His two sons joined the family business after finishing college in California.

COMPLACENCY IS DANGEROUS in Pakistan. During the weeks when Ed Kashi and I were traveling outside Lahore, the Taliban launched a new series of devastating attacks in Punjab — among them a 22-hour siege of the army head-quarters in Rawalpindi that left 23 dead, including the attackers. Returning to Lahore from Sialkot, our car was stopped and searched at one of the new checkpoints that had sprung up overnight around the city. The province appeared to be tilting toward chaos.

It was Bulleh Shah who restored a measure of hope. A champion of free thought, the saint made no distinction among castes or creeds and so offended orthodox clerics that they refused him burial in a communal graveyard. Yet his message of tolerance seemed, if anything, more relevant today than when he died in 1758. On the afternoon before my flight home, I decided to visit his tomb, which is on the outskirts of the town of Kasur, about an hour from Lahore.

The shrine is not especially beautiful or grand, but its spiritual power over Bulleh Shah's acolytes was something to behold. As qawwals warmed up their instruments in preparation for the evening crowd, a trickle of visitors — mostly women — approached the saint's burial chamber in reverent silence. Some sought his blessing by tying colored threads to the chamber's filigreed stone. A few openly wept.

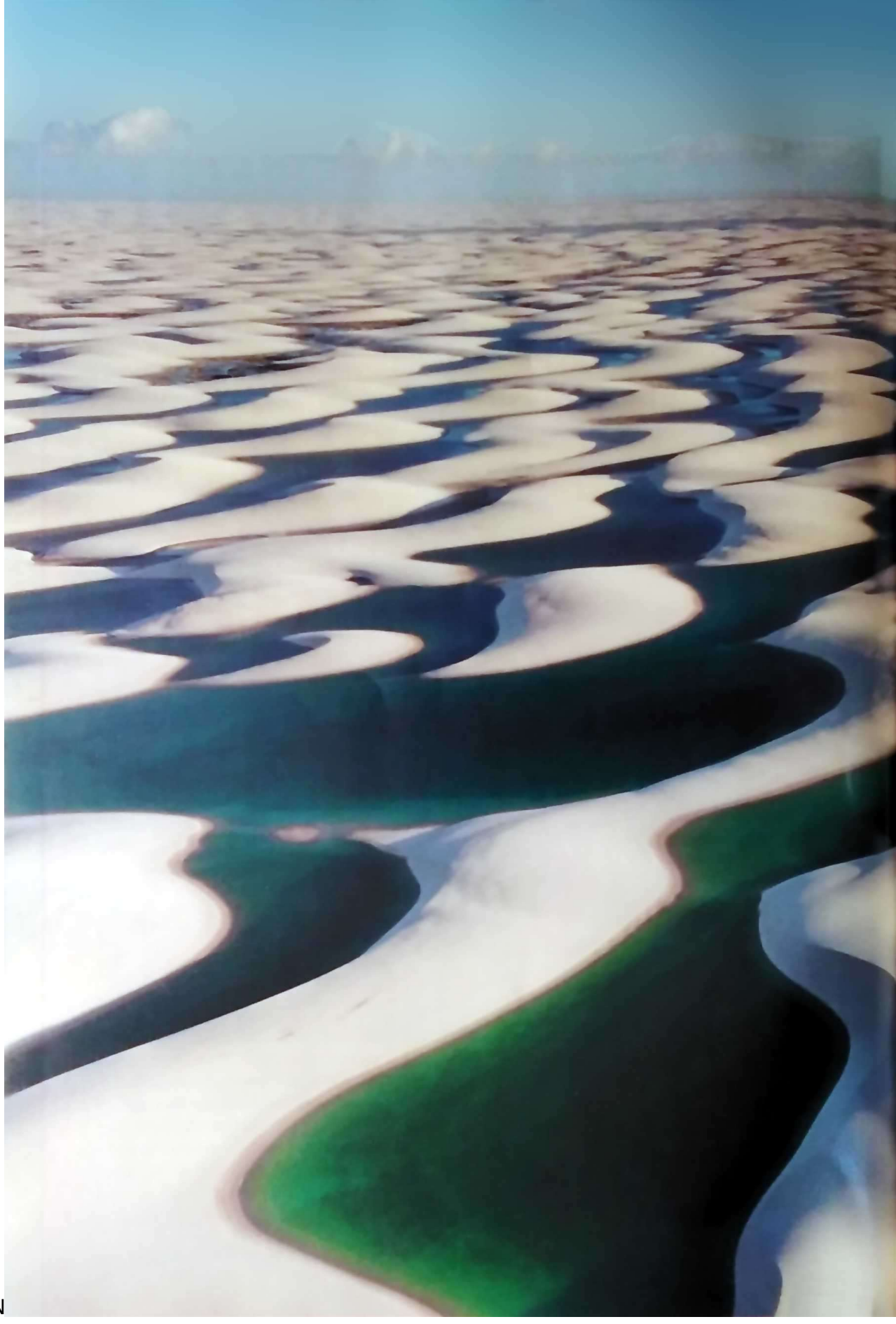
I hadn't been there long when an elderly woman walked up to me and extended a cardboard box. "You must have a sweet", she insisted. "It is being offered in the saint's name". I was touched by this gesture to a stranger, which reassured me that somehow Bulleh Shah's teachings had not been forgotten — and might yet prove more enduring than the Taliban's. The taste of the woman's offering lingered for a long time.

PUNJAB, INDIA
Pakistan got the largest share of Punjab when the subcontinent was divided in 1947. Indian Punjab, however, still has much in common with its neighbor, including their languages.

LAND OF FIVE RIVERS

It's no accident that Punjab is the richest, most populous, and politically important province in Pakistan. Conquerors have long coveted the region for its fertile soil, abundant water, and trading routes between Central Asia and the Indian subcontinent. Foreign influence contributed to a diverse, fundamentally tolerant culture that today is reflected in the pervasiveness of Sufism. But encroachments by the Taliban are testing Punjab's civility and openness.

VICKIE TAYLOR, INTERNATIONAL MAPPING. JEROME N. COOKSON AND MARGUERITE B. HUNSIKER, NGM STAFF. RELIEF BY TIBOR G. TÓTH. IRRIGATED CROPLAND SOURCE: EUROPEAN SPACE AGENCY, ESA GLOBCOVER PROJECT LED BY MEDIAS-FRANCE.



A SEA OF DUNES

Conjured by wind and water,
a magical sandscape on the northeastern
coast of Brazil is no mirage.

By Ronaldo Ribeiro

Photographs by George Steinmetz

In a land still soaked from the rainy season, a river stained with tannin from a nearby forest marbles the sand (below), and water plants float on swimming stems (left). Preceding pages: Ribbons of dunes trap the rains.

Raised by residents of the park, goats graze freely on wild vegetation during the lush months of rain, then are rounded up when the dry season arrives.

SEEN FROM THE AIR, the dunes look like white linens hung out to dry on a windy afternoon. In fact, the name of this place, Lençóis Maranhenses, means the “bedsheets of Maranhão”, the state in Brazil on the tropical northeastern coast where the halfmoon-shaped dunes are found. By any name it is a magical desert, with wave after wave of shimmering white sand. Shoals of silvery fish swim in brilliant blue and green pools left behind by the rains. Shepherds lead caravans of goats over towering dunes. And fishermen head out to sea, guided only by the stars and the ghosts of old shipwrecks.

“It feels like a parallel world”, says Carolina Alvite, former director of the 600-square-mile national park created three decades ago to protect this unlikely ecosystem. It's as if the sea near the Bahamas suddenly appeared like a mirage in the middle of the Sahara.

Only in this desert the mirage is real.

Actually, by the most technical of standards, the Lençóis isn't really a desert, says Antonio Cordeiro Feitosa, a geographer at the Federal University of Maranhão. Forty-seven inches or so of rain fall on the region a year. By definition, a desert averages fewer than ten inches a year.

And it is the presence of water that makes the sandscape possible. Two nearby rivers, the Parnaiba and Preguiças, carry sand from the interior of the continent to the Atlantic, where ocean currents push them westward. Much of the sediment is deposited along the park’s 44-mile-long shoreline. Here, during the dry season, especially in October and November, a relentless northeasterly wind drives the sand as far as 30 miles inland, sculpting crescent-shaped dunes up to 130 feet high as far as the eye can see. Cordeiro’s eye also sees the perpetual motion of Lençóis Maranhenses. In places these dunes may advance by as much as 65 feet a year. “The landscape is radically transformed by each seasonal cycle”, he says.

George Steinmetz photographed Libya’s Sahara for the October 2009 issue.
Ronaldo Ribeiro is the senior editor of the Geographic’s Brazilian edition.

Lagoons are born anew each year after the January-to-June rains fill the valleys between the dunes. Some of these temporary bodies of water are more than 300 feet long and up to ten feet deep. In early July, at their fullest, the lagoons can become interconnected when rivers, such as the Rio Negro, cut through the dunes. So fish have a route to migrate into the lagoons, where they feed on other fish or the larvae of insects buried in the sand. A few fish species, such as the wolffish (*Hoplias malabaricus*), even spend the dry season dormant in the mud, emerging when the showers return. Once the rainy season ends, the lagoons begin to evaporate in the equatorial heat; their water level may drop by as much as three feet a month.

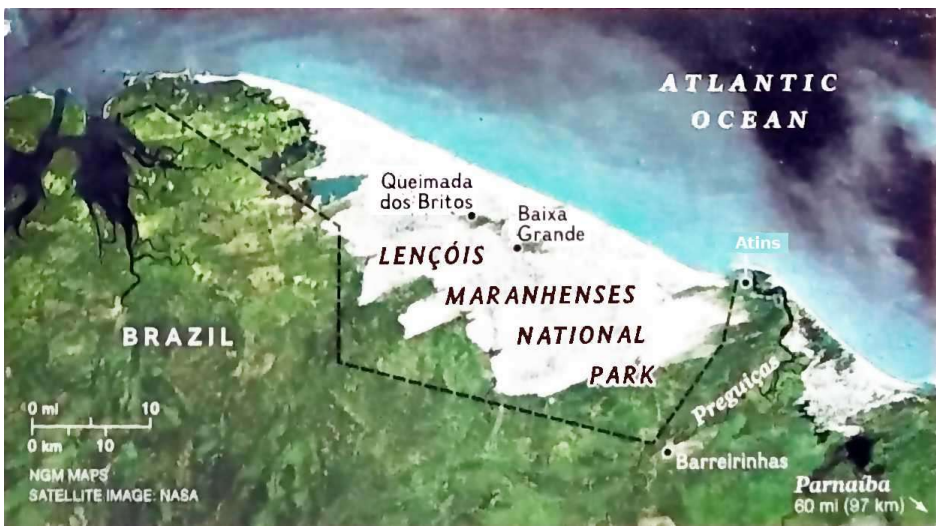
Fish and bugs aren't the only residents. Besides people living in villages around the dunes, 90 men, women, and children inhabit two oases in the dunes, Queimada dos Britos and Baixa Grande, where they dwell in palm-roofed mud huts. Like the dunes, they change their routines with the seasons. In the dry season they raise chickens, goats, and cattle, grow cassava, beans, and cashews, and collect buriti and carnauba palm fibers from the *restinga*, or coastal vegetation, that grows near the dunes. When the rains come and planting becomes more difficult, people in the oases head for the sea, where they live in fishing camps on the beach. There they sell salted and dried Atlantic tarpon and other fish to traders, who sell them in the cities.

In 2002 a highway was paved between the capital of Maranhão, São Luís, and Barreirinhas, a rapidly growing country town that now promotes itself as the entry point to the park. Since then, tourism has also increased, with more than 60,000 park visitors a year now, and joyriding on the dunes on all-terrain vehicles has become a big concern for park officials.

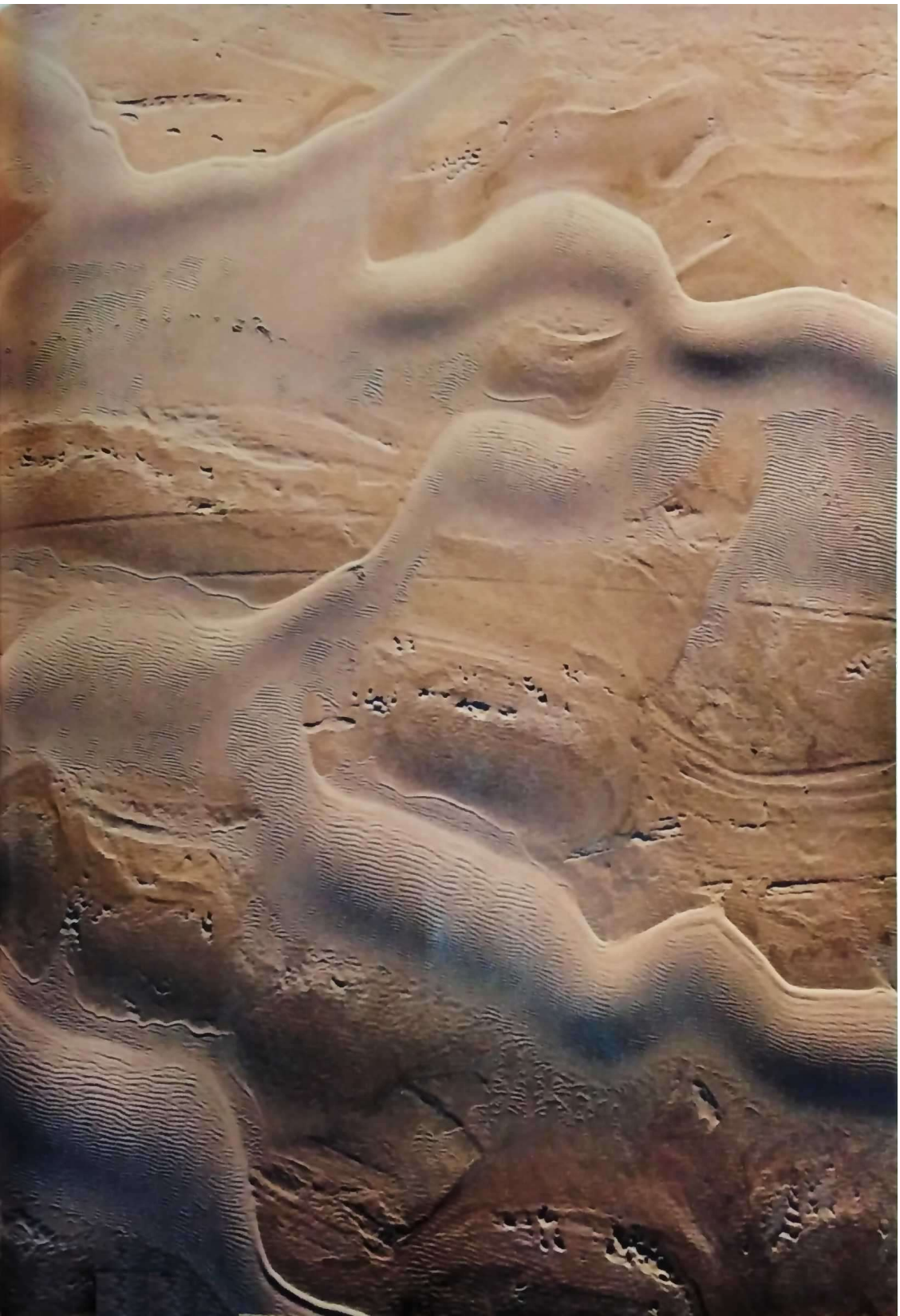
“Vehicles are forbidden on the dunes”, says Alvite, who worries that such reckless activities pose a threat to migratory sandpipers and terns as well as the birds that nest there. In an effort to promote a more sustainable kind of tourism, she led a group in 2009 on a 40-mile hike from one side of the park to the other to look for signs of dune creatures, including the Brazilian slider turtle (*Trachemys adiutrix*), the yellow armadillo (*Euphractus sexcinctus*), and the white-eared opossum (*Didelphis albiventris*).

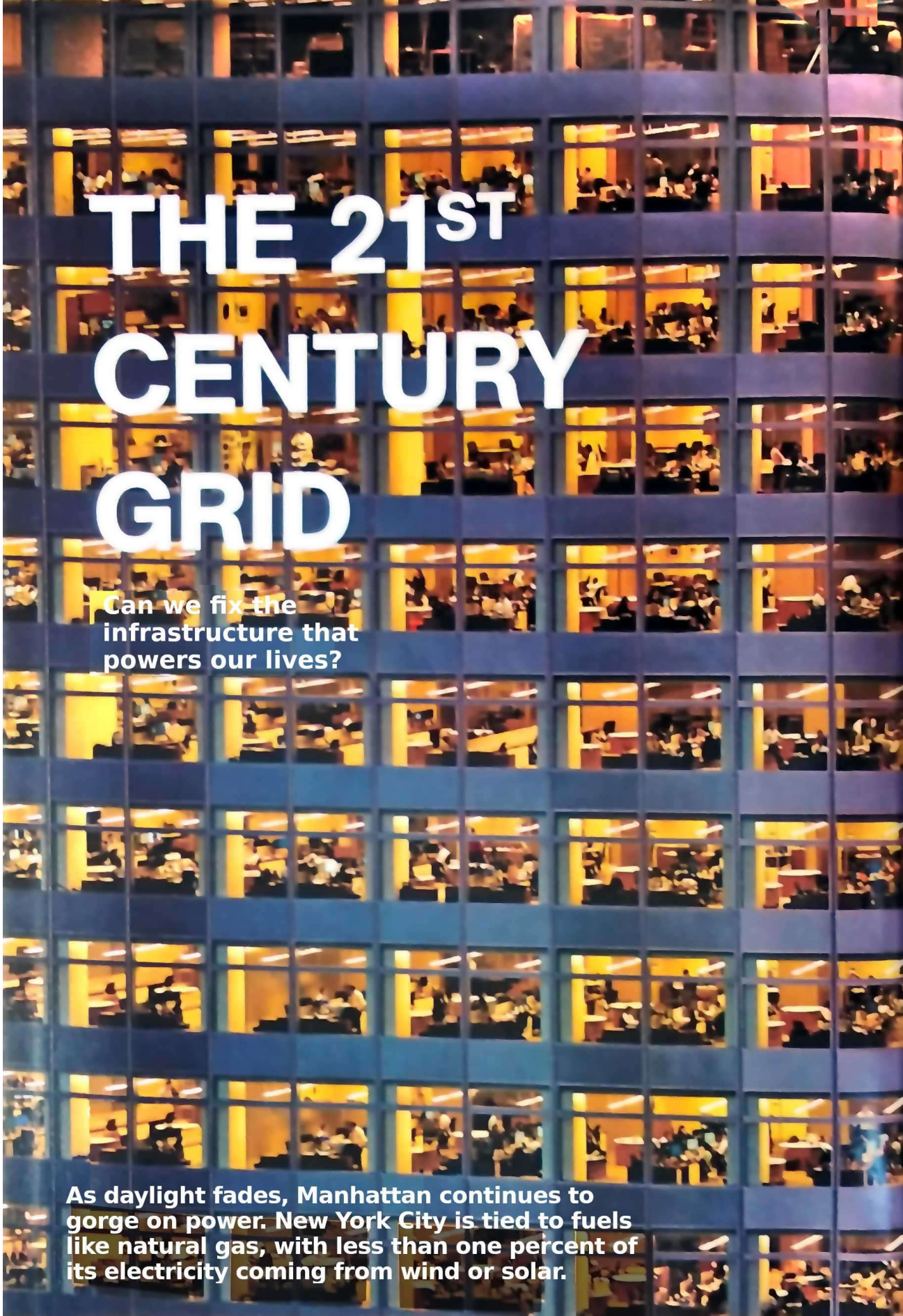
It's no wonder that outsiders want to visit this otherworldly place, the largest coastal dune field in Brazil. Even those who know it best are surprised by its constantly shifting beauty. Manoel Brito, the late patriarch of Queimada dos Britos, used to keep a herd of 500 or so goats that roamed freely through the sands. Wandering over the dunes with his herd, he would marvel at the way the sands kept on the move. “Everything here always looks the same”, he once told me. “But every day, if you look carefully, you'll see that the sand is in a different place. God created these white mountains and made the wind play with them forever”.

The park’s dazzling sands stretch some 44 miles along Brazil’s northeastern coast.



Waves of sand, firmed by an overnight rain, flow along the route of a fisherman pedaling his catch at dawn to trade it for supplies. When the dune dries in a day or so, the wind will begin to reshape it once again.





THE 21ST CENTURY GRID

Can we fix the infrastructure that powers our lives?

As daylight fades, Manhattan continues to gorge on power. New York City is tied to fuels like natural gas, with less than one percent of its electricity coming from wind or solar.

NA

Helicopter drop-ins were the only way to build much of a new transmission line through southern California's Angeles National Forest. It will bring wind power to as many as three million homes.

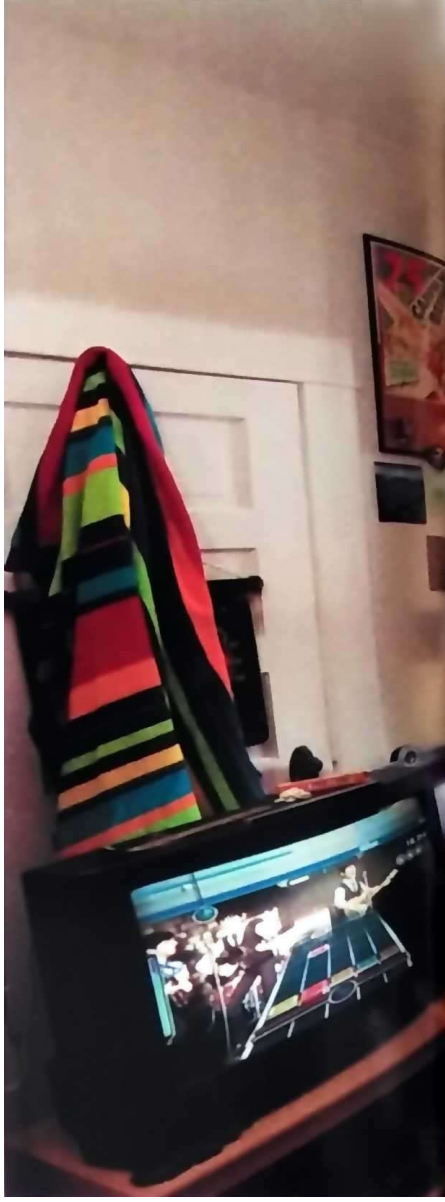
BY JOEL ACHENBACH

PHOTOGRAPHS BY JOE McNALLY

WE ARE CREATURES OF THE GRID. We are embedded in it and empowered by it. The sun used to govern our lives, but now, thanks to the grid, darkness falls at our convenience. During the Depression, when power lines first electrified rural America, a farmer in Tennessee rose in church one Sunday and said — power companies love this story — “The greatest thing on earth is to have the love of God in your heart, and the next greatest thing is to have electricity in your house”. He was talking about a few lightbulbs and maybe a radio. He had no idea.

Juice from the grid now penetrates every corner of our lives, and we pay no more attention to it than to the oxygen in the air. Until something goes wrong, that is, and we're suddenly in the dark, fumbling for flashlights and candles, worrying about the frozen food in what used to be called (in pre-grid days) the icebox. Or until the batteries run dry in our laptops or smart phones, and we find ourselves scouring the dusty corners of airports for an outlet, desperate for the magical power of electrons.

The grid is wondrous. And yet — in part because we've paid so little attention to it, engineers tell us — it's not the grid we need for the 21st century. It's too old. It's reliable but not reliable enough, especially in the United States, especially for our mushrooming population of finicky digital devices. Blackouts, brownouts, and other power outs cost Americans an estimated $80 billion a year. And at the same time that it needs to become more reliable, the grid needs dramatic upgrading to handle a different kind of power, a greener kind. That means, among other things, more transmission lines to carry wind power and solar power from remote places to big cities.



From PlayStations to iMacs, the small electronic devices that appeal to Corbin Stafford (at right) and Aaron Bear Paul, of Boulder, Colorado, have a big impact. Worldwide they account for about 15 percent of residential electricity consumption.

Most important, the grid must get smarter. The precise definition of “smart” varies from one engineer to the next. The gist is that a smart grid would be more automated and more “self-healing”, and so less prone to failure. It would be more tolerant of small-scale, variable power sources such as solar panels and wind turbines, in part because it would even out fluctuations by storing energy — in the batteries of electric cars, according to one speculative vision of the future, or perhaps in giant caverns filled with compressed air.

But the first thing a smart grid will do, if we let it, is turn us into savvier consumers of electricity. We'll become aware of how much we’re consuming and cut back, especially at moments of peak demand, when electricity costs most to produce. That will save us and the utilities money — and incidentally reduce pollution. In a way, we’ll stop being mere passive consumers of electrons. In the 21st century we'll become active participants in the management of this vast and seemingly unknowable network that makes our civilization possible.

So maybe it’s time we got to know it.

Joel Achenbach wrote last August’s cover story on the Yellowstone supervolcano.

For more on what Joe McNally had to do to get the photos, see page 140.

AT 4:13 P.M. LIGHTS WENT OUT IN THE CONTROL

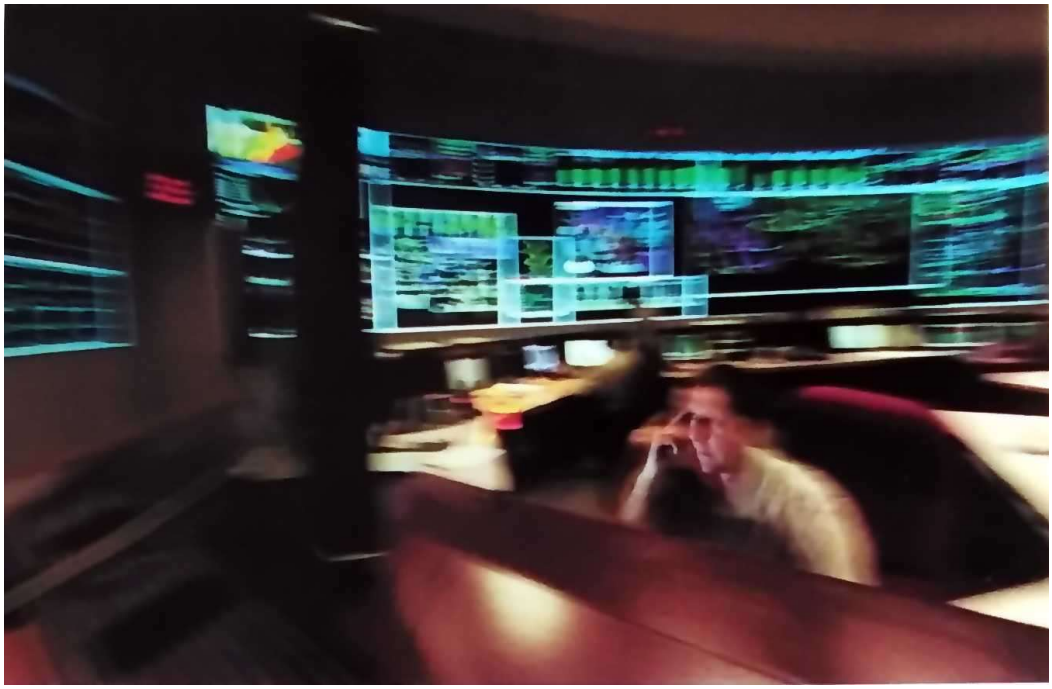
The brains of the electrical grid, control centers match supply and demand to avoid a repeat of disasters like the 2003 blackout that struck New York and much of the Northeast. In Pennsylvania, PJM Interconnection, a large regional operator, is replacing its old control room (right) with two new ones — a safeguard against an emergency.

THERE ARE GRIDS today on six continents, and someday Europe's may reach across the Mediterranean into Africa to carry solar power from the Sahara to Scandinavia. In Canada and the U.S. the grid carries a million megawatts across tens of millions of miles of wire. It has been called the world's biggest machine. The National Academy of Engineering calls it the greatest engineering achievement of the last century.

Thomas Edison, already famous for his lightbulb, organized the birth of the grid in 1881, digging up lower Manhattan to lay down copper wires inside brick tunnels. He constructed a power plant, the Pearl Street Station, in the shadow of the Brooklyn Bridge. On September 4, 1882, in the office of tycoon J. P. Morgan, Edison threw a switch. Hundreds of his bulbs lit up Drexel, Morgan & Co. and other offices nearby.

Edison was heavily invested in direct current, which worked well in his bulbs and which at the time was low voltage. Alternating current, he argued colorfully, was more appropriate to executing criminals. (He had a circus elephant electrocuted to prove his point.) The argument was misleading: AC, in which the electrons don't stream in one direction but oscillate back and forth at a given frequency, isn't intrinsically more dangerous than DC. High voltage is what's dangerous — but it's also what allows power to be transmitted hundreds of miles without excessive loss. AC won out over DC largely because it can easily be stepped up with transformers, transmitted, then stepped down again to a safer household voltage of 110 or 220. By the 1890s AC lines were running from the new Niagara Falls generating station to Buffalo, some 20 miles away. These days, ironically, high-voltage DC is sometimes preferred for very long distances; it's harder to produce than AC, but it loses even less power.

ROOM. THE OPERATORS THOUGHT: 9/11.



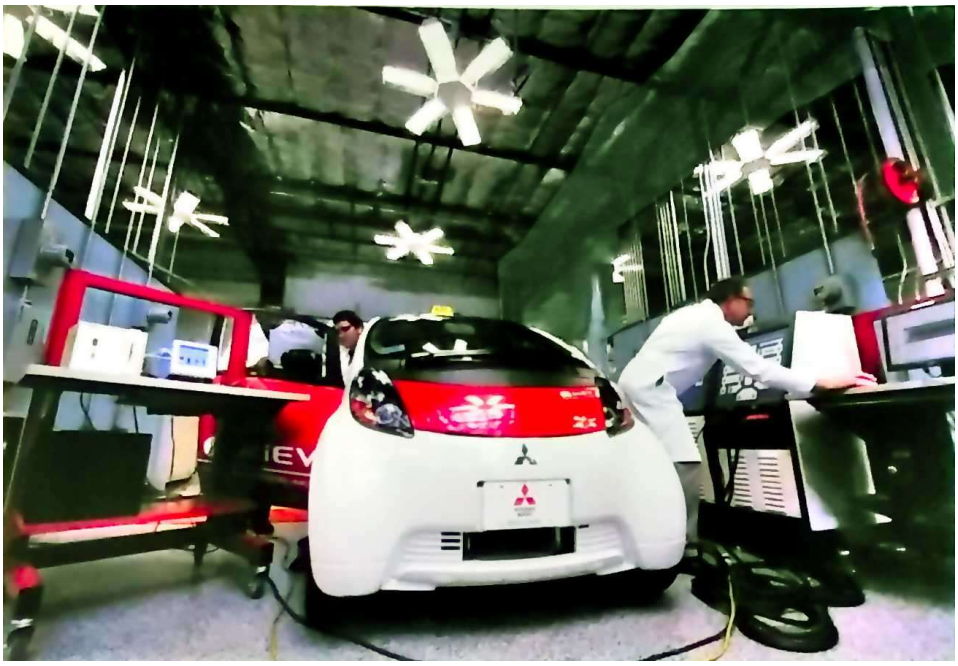
It took decades for electricity to expand from factories and mansions into the homes of the middle class. In 1920 electricity still accounted for less than 10 percent of the U.S. energy supply. But inexorably it infiltrated everyday life. Unlike coal, oil, or gas, electricity is clean at the point of use. There is no noise, except perhaps a faint hum, no odor, and no soot on the walls. When you switch on an electric lamp, you don't think of the huge, sprawling power plant that's generating the electricity (noisily, odoriferously, sootily) many miles away. Refrigerators replaced iceboxes, air conditioners replaced heat prostration, and in 1956 the electric can opener completed our emergence from the dark ages. Today about 40 percent of the energy we use goes into making electricity.

At first, utilities were local operations that ran the generating plant and the distribution. A patchwork of mini-grids formed across the U.S. In time the utilities realized they could improve reliability and achieve economies of scale by linking their transmission networks. After the massive Northeast blackout of 1965, much of the control of the grid shifted to regional operators spanning many states. Yet today there is still no single grid in the U.S.; there are three nearly independent ones — the Eastern, Western, and Texas Interconnections.

They function with antiquated technology. The parts of the grid you come into contact with are symptomatic. How does the power company measure your electricity usage? With a meter reader — a human being who goes to your home or business and reads the dials on a meter. How does the power company learn that you've lost power? When you call on the phone. In general, utilities don't have enough instantaneous information on the flow of current through their lines — many of those lines don't carry any data — and people and slow mechanical switches are too involved in controlling that flow.

“The electrical grid is still basically 1960s technology”, says physicist Phillip P. Schewe, author of *The Grid*. “The Internet has passed it by. The meter on the side of your house is 1920s technology”. Sometimes that quaintness becomes a problem. On the grid these days, things can go bad very fast.

THE ELECTRICITY FLOWING IN YOUR LIGHTBULB



Southern California Edison's fleet of electric vehicles, almost 300 strong, has logged 18.3 million tailpipe-emission-free miles. Its test center evaluates how cycles of charging and discharging affect vehicle batteries — which one day may not only draw energy from the grid but also return some at moments of peak demand.

WHEN YOU FLIP A LIGHT SWITCH, the electricity that zips into the bulb was created just a fraction of a second earlier, many miles away. Where it was made, you can't know, because hundreds of power plants spread over many states are all pouring their output into the same communal grid. Electricity can't be stored on a large scale with today's technology; it has to be used instantly. At each instant there has to be a precise balance between generation and demand over the whole grid. In control rooms around the grid, engineers constantly monitor the flow of electricity, trying, to keep voltage and frequency steady and to avoid surges that could damage both their customers' equipment and their own.

When I flip a switch at my house in Washington, D.C., I'm dipping into a giant pool of electricity called the PJM Interconnection. PJM is one of several regional operators that make up the Eastern grid; it covers the District of Columbia and 13 states, from the Mississippi River east to New Jersey and all the way down to the Outer Banks of North Carolina. It's an electricity market that keeps supply and demand almost perfectly matched — every day, every minute, every fraction of a second — among hundreds of producers and distributors and 51 million people, via 56,350 miles of high-voltage transmission lines.

One of PJM's new control centers is an hour north of Philadelphia. Last February I went to visit it with Ray E. Dotter, a company spokesman. Along the way Dotter identified the power lines we passed under. There was a pair of 500-kilovolt lines linking the Limerick nuclear plant with the Whitpain substation. Then a 23O-kilovolt line. Then another. Burying the ungainly lines is prohibitively expensive except in dense dries. "There's a need to build new lines", Dotter said. "But no matter where you propose them, people don't want them".

WAS MADE AN INSTANT AGO, MANY MILES AWAY.

Dotter pulled off the turnpike in the middle of nowhere. A communications tower poked above the treetops. We drove onto a compound surrounded by a security fence. Soon we were in the bunker, built by AT&T during the Cold War to withstand anything but a direct nuclear hit and recently purchased by PJM to serve as its new nerve center.

In the windowless control room, dominated by a curved wall of 36 computer screens, dispatch general manager Mike Bryson explained what I was seeing. A dynamic map on one of the screens showed the PJM part of the grid. Arrows represented major transmission lines, each with a number showing how much juice was on the line at that moment. Most of the arrows pointed west to east: In the eastern U.S. electricity flows from major power plants in the heartland toward huge clusters of consumers along the eastern seaboard. At that moment PJM lines were carrying 88,187 megawatts. “Today is a mild winter day — I don't think we'll have over 90,000”, Bryson said.

The computers take data from 65,000 points on the system, he explained. They track the thermal condition of the wires; too much power flowing through a line can overheat it, causing the line to expand and sag dangerously. PJM engineers try to keep the current alternating at a frequency of precisely 60 hertz. As demand increases, the frequency drops, and if it drops below 59.95 hertz, PJM sends a message to power plants asking for more output. If the frequency increases above 60.05 hertz, they ask the plants to reduce output.

It sounds simple, but keeping your balance on a tightrope might sound simple too until you try it. In the case of the grid, small events not under the control of the operators can quickly knock down the whole system.

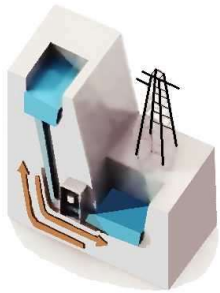
Which brings us to August 14, 2003. Most of PJM’s network escaped the disaster, which started near Cleveland. The day was hot; the air conditioners were humming. Shortly after 1 p.m. EDT, grid operators at First Energy, the regional utility, called power plants to plead for more volts. At 1:36 p.m. on the shore of Lake Erie, a power station whose operator had just promised to “push it to my max max” responded by crashing. Electricity surged into northern Ohio from elsewhere to take up the slack.

ENERGY STORAGE

Because wind and solar power are intermittent, the quest is on to find ways to store energy for round-the-clock dlstribution — fueled in part by $185 million in stimulus money. Here are four promising technologies.

Compressed air, stored underground
An Iowa wind farm plans to pump air into sand-stone formations when there's wind. Later the air can be released to make electricity.

Sodium-sulfur batteries
Pioneered in Japan, this technology can store a large amount of energy in a small space, as lithium-ion batteries do for electric cars.



Pumped-storage hydropower
Water is pumped uphill into a reservoir when electricity demand is low and released again to turn a turbine when demand is high.

Flywheel storage
In one town in Australia, electricity from wind turbines powers flywheels; their spinning motion is used to regenerate electricity when it's needed.

ART: BRYAN CHRISTIE
SOURCES: U. S. DEPARTMENT OF ENERGY; ENERGY STORAGE ASSOCIATION; ESKOM

ONE THING THE GRID NEEDS TO BECOME GREEN:

At 3:05 a 345-kilovolt transmission line near the town of Walton Hills picked that moment to short out on a tree that hadn't been trimmed. That failure diverted electricity onto other lines, overloading and overheating them. One by one, like firecrackers, those lines sagged, touched trees, and short-circuited.

Grid operators have a term for this: “cascading failures”. The First Energy operators couldn't see the cascade coming because an alarm system had also failed. At 4:06 a final line failure sent the cascade to the East Coast. With no place to park their electricity, 265 power plants shut down. The largest blackout in North American history descended on 50 million people in eight states and Ontario.

At the Consolidated Edison control center in lower Manhattan, operators remember that afternoon well. Normally the power load there dips gradually, minute by minute, as workers in the city turn off their lights and computers and head home. Instead, at 4:13 p.m. lights went out in the control room itself. The operators thought: 9/11. Then the phone rang, and it was the New York Stock Exchange. “What's going on?” someone asked. The operators knew at once that the outage was citywide.

There was no stock trading then, no banking, and no manufacturing; restaurants closed, workers were idled, and everyone just sat on the stoops of their apartment buildings. It took a day and a half to get power back, one feeder and substation at a time. The blackout cost six billion dollars. It also alarmed Pentagon and Homeland Security officials. They fear the grid is indeed vulnerable to terrorist attack, not just to untrimmed trees.

THE BLACKOUT AND GLOBAL WARMING have provided a strong impetus for grid reform. The federal govermnent is spending money on the grid — the economic-stimulus package allocated $4.5 billion to smart grid projects and another six billion dollars or so to new transmission lines. Nearly all the major utilities have smart grid efforts of their own.

A smarter grid would help prevent blackouts in two ways. Faster, more detailed feedback on the status of the grid would help operators stay ahead of a failure cascade. Supply and demand would also be easier to balance, because controllers would be able to tinker with both. “The way we designed and built the power system over the last hundred years — basically the way Edison and Westinghouse designed it — we create the supply side”, says Steve Hauser of the U.S. Department of Energy’s National Renewable Energy Laboratory (NREL) near Boulder, Colorado. “We do very little to control demand”.

Working with the NREL, Xcel Energy has brought smart grid technology to Boulder. The first step is the installation of smart meters that transmit data over fiber-optic cable (it could also be done wirelessly) to the power company. Those meters allow consumers to see what electricity really costs at different times of day; it costs more to generate during times of peak load, because the utilities have to crank up auxiliary generators that aren't as efficient as the huge ones they run 24/7.

When consumers are given a price difference, they can choose to use less of the expensive electricity and more of the cheap kind. They can run clothes dryers and dishwashers at night, for instance. The next step is to let grid operators choose. Instead of only increasing electricity supply to meet demand, the operators could also reduce demand. On sweltering summer days the smart grid could automatically turn up thermostats and refrigerators a bit — with the prior agreement of the homeowners of course.

“Demand management” saves energy, but it could also help the grid handle renewable energy sources. One of the biggest problems with renewables like solar and wind power is that they're intermittent. They're not always available when demand peaks. Reducing the peak alleviates that problem. You can even imagine programming smart appliances to operate only when solar or wind power is available.

LONG-DISTANCE, HIGH-VOLTAGE POWER LINES.

Superconducting cables at the Long Island Power Authority were turned on in 2008. They can move two to five times as much power as conventional cables of the same size, freeing valuable space in crowded transmission corridors and postponing or eliminating the need to upgrade transmission systems for higher voltages.

Some countries, such as Italy and Sweden, are ahead of the U.S. in upgrading their electrical intelligence. The Boulder project went online earlier this year, but only about 10 percent of U.S. customers have even the most primitive of smart meters, Hauser estimates.

"It's expensive", he says. "Utilities are used to spending 40 bucks on an old mechanical meter that's got spinning dials. A smart meter with a software chip, plus the wireless communication, might cost $200 — five times as much. For utilities, that's huge". The Boulder project has cost Xcel Energy nearly three times what it expected. Earlier this year the utility raised rates to try to recoup some of those costs.

ALTHOUGH EVERYONE ACKNOWLEDGES the need for a better, smarter, cleaner grid, the paramount goal of the utility industry continues to be cheap electricity. In the U.S. about half of it comes from burning coal. Coal-powered generators produce a third of the mercury emissions in America, a third of our smog, two-thirds of our sulfur dioxide, and nearly a third of our planet-warming carbon dioxide — around 2.5 billion metric tons a year, by the most recent estimate.

Not counting hydroelectric plants, only about 3 percent of American electricity comes from renewable energy. The main reason is that coal-fired electricity costs a few cents a kilowatt-hour, and renewables cost substantially more. Generally they're competitive only with the help of government regulations or tax incentives. Utility executives are a conservative bunch. Their job is to keep the lights on. Radical change makes them nervous; things they can't control, such as government policies, make them nervous. "They tend to like stable environments", says Ted Craver, head of Edison International, a utility conglomerate, "because they tend to make very large capital investments and eat that cooking for 30 or 40 or 50 years".

So windmills worry them. A utility executive might look at one and think: What if the wind doesn't blow? Or look at solar panels and think: What if it gets cloudy? A smart grid alone can't solve the intermittence problem. The ultimate solution is finding ways to store large amounts of electricity for a rainy, windless day.

Actually the U.S can already store around 2 percent of its summer power output — and Europe even more — behind hydroelectric dams. At night, when electricity is cheaper, some utilities use it to pump water back uphill into their reservoirs, essentially storing electricity for the next day. A small power plant in Alabama does something similar; it pumps air into an underground cavern at night, compressing it to more than a thousand pounds per square inch. During the day the compressed air comes rushing out and spins a turbine. In the past year the Department of Energy has awarded stimulus money to several utilities for compressed-air projects. One project in Iowa would use wind energy to compress the air.

Another way to store electricity, of course, is in batteries. For the moment, it makes sense on a large scale only in extreme situations. For example, the remote city of Fairbanks, Alaska, relies on a huge nickel-cadmium, emergency-backup battery. It's the size of a football field.

Lithium-ion batteries have more long-term potential — especially the ones in electric or plug-in-hybrid cars. PJM is already paying researchers at the University of Delaware $200 a month to store juice in three electric Toyotas as a test of the idea. The cars draw energy from the grid when they're charging, but when PJM needs electricity to keep its frequency stable, the cars are plugged in to give some back. Many thousands of cars, the researchers say, could someday function as a kind of collective battery for the entire grid. They would draw electricity when wind and solar plants are generating, and then feed some back when the wind dies down or night falls or the sun goes behind clouds. The Boulder smart grid is designed to allow such two-way flow.

To accommodate green energy, the grid needs not only more storage but more high-voltage power lines. There aren't enough running to the places where it's easy to generate the energy. To connect wind farms in Kern County with the Los Angeles area, Southern California Edison, a subsidiary of Edison International, is building 250 miles of them, known as the Tehachapi Renewable Transmission Project. A California law requires utilities to generate at least 20 percent of their electricity from renewable sources as of this year.

Green energy would also get a boost if there were more and bigger connections between the three quasi-independent grids in the U.S. West Texas is a Saudi Arabia of wind, but the Texas Interconnection by itself can't handle all that energy. A proposed project called the Tres Amigas Superstation would allow Texas wind — and Arizona sun — to supply Chicago or Los Angeles. Near Clovis, New Mexico, where the three interconnections already nearly touch, they would be joined together by a loop of five-gigawatt-capacity superconducting cable. The three grids would become, in effect, one single grid, national and almost rational.

STUDYING THE MAP OF THE GRID in the PJM control room, I noticed unfamiliar place-names: Amos, Pruntytown, Matt Funk, Sporn. Washington, D.C., was not labeled; Mike Bryson suggested it was somewhere near a substation called Waugh Chapel. One of the largest generating stations on the map, he added helpfully, was the Gavin plant, which at that moment was cranking out 2,633 megawatts.

Where's Gavin? I asked.

“West Virginia or Kentucky somewhere”, Bryson said.

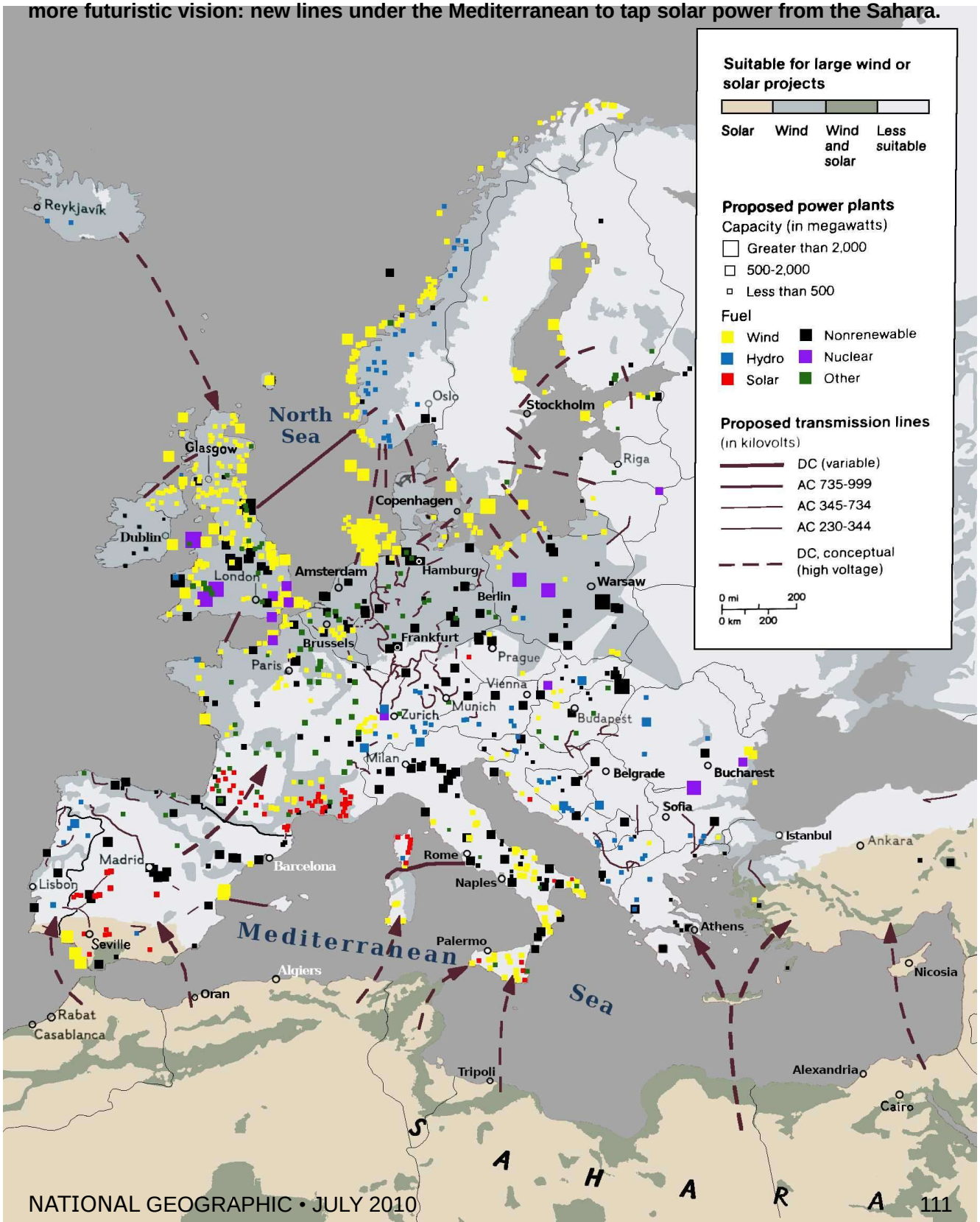
It's actually in southern Ohio. The grid is a kind of parallel world that props up our familiar one but doesn't map onto it perfectly. It's a human construction that has grown organically, like a city or a government — what technical people call a kludge. A kludge is an awkward, inelegant contraption that somehow works. The U.S. grid works well by most measures, most of the time; electricity is abundant and cheap.

It's just that our measures have changed, and so the grid must too. The power industry, says Ted Craver of Edison International, faces “more change in the next ten years than we've seen in the last hundred”. But at least now the rest of us are starting to pay attention.

NGM MAPS SOURCES: 3TIER (SOLAR AND WIND DATA ANALYSIS), PLATTS, A DIVISION OF MCGRAW-HILL COMPANIES (PROPOSED GENERATION AND TRANSMISSION INFRASTRUCTURE); DESERTEC; SUPERSMART GRID (DC CONCEPTUAL NETWORK)

EUROPE'S GRID OF THE FUTURE

Last November 8, more than half of Spain's electricity was wind generated, and it even exported some to its neighbors — a hopeful sign, but one that lasted only a few hours. Europe's goal of getting 20 percent of its energy from renewables by 2020 will require "more of a revolution than an evolution", says Daniel Dobbeni of ENTSO-E, a grid operators association. Nine northern European countries agreed last year to link their grids by building transmission lines under the North Sea. A **more futuristic vision: new lines under the Mediterranean to tap solar power from the Sahara.**



INSIDE GEOGRAPHIC

Joe McNally and crew go for a spin.

ON ASSIGNMENT **Electric Company** Two hundred feet above California's Angeles National Forest, photographer Joe McNally (above, at center) stepped from the top of a high-voltage tower onto the skid of a helicopter. He had spent five days commuting by air to cover the construction of the Tehachapi Renewable Transmission Project, parts of which can't easily be reached by road. When the work was complete, his pilot wanted to have a little fun. Says McNally: "He shouted, 'You want to do a dipsy doodle?'" Then they took a spin — literally. "It felt like we did two 360s", he recalls. "It was the best".

On a Roll For the third time in four years, *National Geographic* has won the "Ellie" (below) for general excellence in a publication with circulation over two million at the American Society of Magazine Editors' National Magazine Awards. The Geographic also took home the photojournalism win for last September's "Shattered Somalia" with photographs by Pascal Maitre. And Garrison Keillor's lively coverage of "Top Ten State Fair Joys", which ran in the July issue, won top prize in the essays category.

Society Updates

NAT GEO CHANNEL

Follow Secretary of State Hillary Clinton around the globe in *Inside the State Department*, airing July 5 at 9 p.m. on the National Geographic Channel.

NG BOOKS

A celebration of a hundred of the world's most fascinating people, places, and things, *Nat Geo Amazing!* is the essential companion to the new National Geographic Channel series of the same name. It will be available in bookstores on June 29 ($19.95).

GeoPuzzle Answers

PHOT OS: DREW GURIAN (TOP); MARK THIES5EN, NGM STAFF

MOODY BIBLE INSTITUTE/NATIONAL GEOGRAPHIC STOCK

Don't Try This at Home Electricity flashes from the thimble-topped fingers of traveling “preacher-scientist” George Speake. From the 1940s into the '60s, he was one in a series of men affiliated with Chicago’s Moody Bible Institute who monstrated religious faith by demonstrating scientific principles. To create the lightning effect, Speake would stand atop an electric transformer coil. The room would darken. Then, at his command, a brief high-frequency current would travel over his skin, up from his feet and out of his fingertips. According to notes accompanying the image, Speake suffered no injury because “the high-frequency juice… is too fast to be felt”. Another reason he stayed safe was his extreme care in setting up the trick: The photo’s notes also warn that the practice was “for spectacle purposes only”. — *Margaret G. Zackowitz*

Flashback Archive Find all the photos at ngm.com.

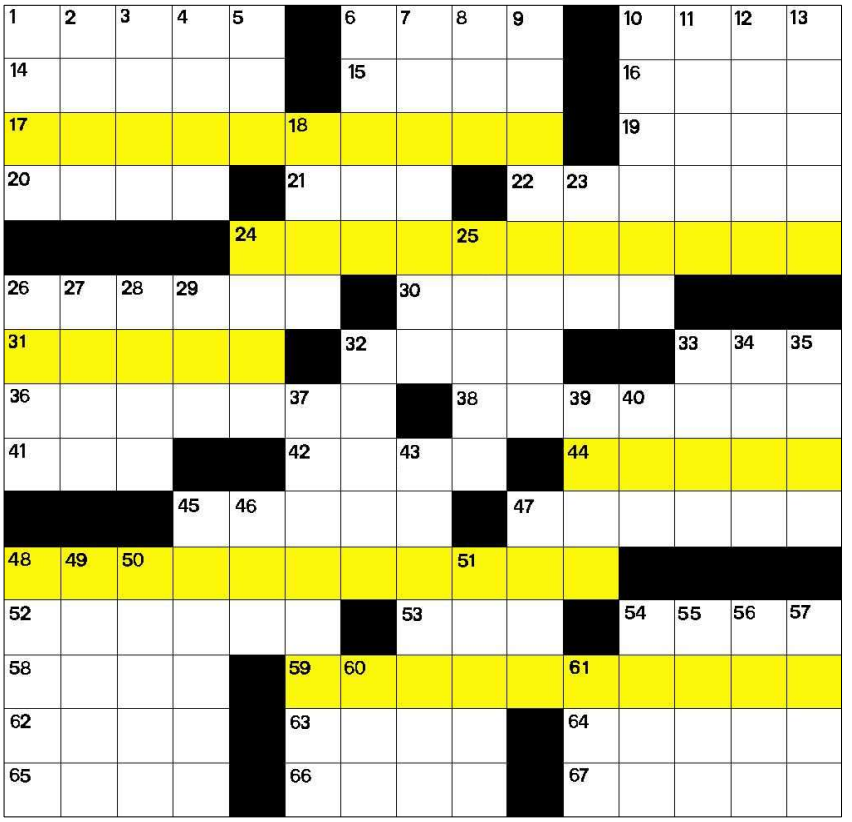
GEOPUZZLE

Gridspeak

Puzzle by Cathy Allis

When the electrical grid (that's what lights up the Empire State Building, right) meets the crossword grid, verbal sparks fly. But as the tinted clues show, what you hear may not be what the speaker intends. Our story on page 118 offers hints on the vocabulary of energy.

JOE McNALLY



ACROSS

1 The electrical grid carries billions of them
6 Forgo
10 Say “Talk to the hand”, say
14 Staggering
15 Mozart opera __ *Fan Tutte*
16 Actress’s fan, perhaps
17 It sounds like the lament of an achy sexagenarian?
19 Prefix meaning “both”
20 Bald spot?
21 With 50 Down, lousy odds
22 Focus (on)
24 It sounds like what a zealous chick might give off?
26 Sound buy
30 Dweebs
31 With 44 Across, it sounds like a bigwig’s suit material?
32 Italian wine district
33 __ *bien* (“very well”: Sp.)
36 Electrical connector
38 California gridiron group
41 There's a long and short of it
42 Sunscreen label abbr.
44 See 31 Across
45 Out, of sorts
47 Artful
48 It sounds like a survey on effectiveness?
52 Sung : cantata :: played : __
53 Thai neighbor
54 “Puppy Love” singer Paul
58 Aardvark’s snack
59 It sounds like an order for a glimpse?
62 Dweeb
63 Fine-tune
64 Kashmir coin
65 Ferber of 12 Down fame
66 Taken in, in a way
67 Like a smart grid, ideally

DOWN

1 Small-waisted stinger
2 A Battle song
3 Let your fingers do the talking?
4 Beret holder
5 Furtive
6 Trailer part
7 They have Seoul
8 Environmental suffix
9 Where food is tossed
10 Hits some splits
11 Heavy metal garb
12 1925 Pulitzer-winning novel by Ferber
13 Having barbs or bristles
18 Jolly laugh
23 He might be tight?
24 Pt. of CPA
25 Ancient city in Jordan, literally “rock”
26 Quarrel
27 Household-list heading
28 Obi-Wan portrayer
29 Unit of ab crunches, e.g.
32 “The Sheik of __”
33 First name in game-show production
34 Craving
35 Belgian river in WWI history
37 Deed language inscriptions?
39 An Aleutian
40 Expected
43 Sopwith Camel, for instance
45 Aleutians location
46 On, thanks to the grid
47 Lummox
48 Meter reader’s finding
49 Firmed at the gym
50 See 21 Across
51 Like some wooden buckets
54 Russian-Chinese border river
55 Scruff
56 Kind of Jerk
57 Yemeni port where the U.S.S. Cole was bombed
60 Job ad abbr.
61 .0000001 Joule